The Reading Brain in the Digital Age: Why Paper Still Beats Screens

One of the most provocative viral YouTube videos in the past two years begins mundanely enough: a one-year-old girl plays with an iPad, sweeping her fingers across its touch screen and shuffling groups of icons. In following scenes, she appears to pinch, swipe and prod the pages of paper magazines as though they, too, are screens. Melodramatically, the video replays these gestures in close-up.

For the girl's father, the video—*A Magazine Is an iPad That Does Not Work*—is evidence of a generational transition. In an accompanying description, he writes, “Magazines are now useless and impossible to understand, for digital natives”—that is, for people who have been interacting with digital technologies from a very early age, surrounded not only by paper books and magazines but also by smartphones, Kindles and iPads.

Whether or not his daughter truly expected the magazines to behave like an iPad, the video brings into focus a question that is relevant to far more than the youngest among us: How exactly does the technology we use to read change the way we read?

Since at least the 1980s researchers in psychology, computer engineering, and library and information science have published more than 100 studies exploring differences in how people read on paper and on screens. Before 1992 most experiments concluded that people read stories and articles on screens more slowly and remember less about them. As the resolution of screens on all kinds of devices sharpened, however, a more mixed set of findings began to emerge. Recent surveys suggest that although most people still prefer paper—especially when they need to concentrate for a long time—attitudes are changing as tablets and e-reading technology improve and as reading digital texts for facts and fun becomes more common. In the U.S., e-books currently make up more than 20 percent of all books sold to the general public.

Despite all the increasingly user-friendly and popular technology, most studies published since the early 1990s confirm earlier conclusions: paper still has advantages over screens as a reading medium. Together laboratory experiments, polls and consumer reports indicate that

digital devices prevent people from efficiently navigating long texts, which may subtly inhibit reading comprehension. Compared with paper, screens may also drain more of our mental resources while we are reading and make it a little harder to remember what we read when we are done. Whether they realize it or not, people often approach computers and tablets with a state of mind less conducive to learning than the one they bring to paper. And e-readers fail to re-create certain tactile experiences of reading on paper, the absence of which some find unsettling.

"There is physicality in reading," says cognitive scientist Maryanne Wolf of Tufts University, "maybe even more than we want to think about as we lurch into digital reading—as we move forward perhaps with too little reflection. I would like to preserve the absolute best of older forms but know when to use the new."

Textual Landscapes

Understanding how reading on paper differs from reading on screens requires some explanation of how the human brain interprets written language. Although letters and words are symbols representing sounds and ideas, the brain also regards them as physical objects. As Wolf explains in her 2007 book *Proust and the Squid*, we are not born with brain circuits dedicated to reading, because we did not invent writing until relatively recently in our evolutionary history, around the fourth millennium b.c. So in childhood, the brain improvises a brand-new circuit for reading by weaving together various ribbons of neural tissue devoted to other abilities, such as speaking, motor coordination and vision.

Some of these repurposed brain regions specialize in object recognition: they help us instantly distinguish an apple from an orange, for example, based on their distinct features, yet classify both as fruit. Similarly, when we learn to read and write, we begin to recognize letters by their particular arrangements of lines, curves and hollow spaces—a tactile learning process that requires both our eyes and hands. In recent research by Karin James of Indiana University Bloomington, the reading circuits of five-year-old children crackled with activity when they practiced writing letters by hand but not when they typed letters on a keyboard. And when people read cursive writing or intricate characters such as Japanese *kanji*, the brain literally goes through the motions of writing, even if the hands are empty.

Beyond treating individual letters as physical objects, the human brain may also perceive a text in its entirety as a kind of physical landscape. When we read, we construct a mental representation of the text. The exact nature of such representations remains unclear, but some researchers think they are similar to the mental maps we create of terrain—such as mountains and trails—and of indoor physical spaces, such as apartments and offices. Both anecdotally and in published studies, people report that when trying to locate a particular passage in a book, they often remember where in the text it appeared. Much as we might recall that we passed the red farmhouse near the start of a hiking trail before we started climbing uphill through the forest, we remember that we read about Mr. Darcy rebuffing Elizabeth Bennett at a dance on the bottom left corner of the left-hand page in one of the earlier chapters of Jane Austen's *Pride and Prejudice*.

In most cases, paper books have more obvious topography than on-screen text. An open paper book presents a reader with two clearly defined domains—the left- and right-hand pages—and a total of eight corners with which to orient oneself. You can focus on a single page of a paper book without losing awareness of the whole text. You can even feel the thickness of the pages you have read in one hand and the pages you have yet to read in the other. Turning the pages of a paper book is like leaving one footprint after another on a trail—there is a rhythm to it and a visible record of how far one has traveled. All these features not only make the text in a paper book easily navigable, they also make it easier to form a coherent mental map of that text.

In contrast, most digital devices interfere with intuitive navigation of a text and inhibit people from mapping the journey in their mind. A reader of digital text might scroll through a seamless stream of words, tap forward one page at a time or use the search function to immediately locate a particular phrase—but it is difficult to see any one passage in the context of the entire text. As an analogy, imagine if Google Maps allowed people to navigate street by individual street, as well as to teleport to any specific address, but prevented them from zooming out to see a neighborhood, state or country. Likewise, glancing at a progress bar gives a far more vague sense of place than feeling the weight of read and unread pages. And although e-readers and tablets replicate pagination, the displayed pages are ephemeral. Once read, those pages vanish. Instead of hiking the trail yourself, you watch the trees, rocks and

moss pass by in flashes, with no tangible trace of what came before and no easy way to see what lies ahead.

"The implicit feel of where you are in a physical book turns out to be more important than we realized," says Abigail J. Sellen of Microsoft Research Cambridge in England, who co-authored the 2001 book *The Myth of the Paperless Office*. "Only when you get an e-book do you start to miss it. I don't think e-book manufacturers have thought enough about how you might visualize where you are in a book."

Exhaustive Reading

At least a few studies suggest that screens sometimes impair comprehension precisely because they distort people's sense of place in a text. In a January 2013 study by Anne Mangen of the University of Stavanger in Norway and her colleagues, 72 10th grade students studied one narrative and one expository text. Half the students read on paper, and half read PDF files on computers. Afterward, students completed reading comprehension tests, during which they had access to the texts. Students who read the texts on computers performed a little worse, most likely because they had to scroll or click through the PDFs one section at a time, whereas students reading on paper held the entire texts in their hands and quickly switched between different pages. "The ease with which you can find out the beginning, end, and everything in between and the constant connection to your path, your progress in the text, might be some way of making it less taxing cognitively," Mangen says. "You have more free capacity for comprehension."

Other researchers agree that screen-based reading can dull comprehension because it is more mentally taxing and even physically tiring than reading on paper. E-ink reflects ambient light just like the ink on a paper book, but computer screens, smartphones and tablets shine light directly on people's faces. Today's LCDs are certainly gentler on eyes than their predecessor, cathode-ray tube (CRT) screens, but prolonged reading on glossy, self-illuminated screens can cause eyestrain, headaches and blurred vision. In an experiment by Erik Wästlund, then at Karlstad University in Sweden, people who took a reading comprehension test on a computer scored lower and reported higher levels of stress and tiredness than people who completed it on paper.

In a related set of Wästlund's experiments, 82 volunteers completed the same reading comprehension test on computers, either as a paginated document or as a continuous piece of text. Afterward, researchers assessed the students' attention and working memory—a collection of mental talents allowing people to temporarily store and manipulate information in their mind. Volunteers had to quickly close a series of pop-up windows, for example, or remember digits that flashed on a screen. Like many cognitive abilities, working memory is a finite resource that diminishes with exertion.

Although people in both groups performed equally well, those who had to scroll through the unbroken text did worse on the attention and working memory tests. Wästlund thinks that scrolling—which requires readers to consciously focus on both the text and how they are moving it—drains more mental resources than turning or clicking a page, which are simpler and more automatic gestures. The more attention is diverted to moving through a text, the less is available for understanding it. A 2004 study conducted at the University of Central Florida reached similar conclusions.

An emerging collection of studies emphasizes that in addition to screens possibly leeching more attention than paper, people do not always bring as much mental effort to screens in the first place. Based on a detailed 2005 survey of 113 people in northern California, Ziming Liu of San Jose State University concluded that those reading on screens take a lot of shortcuts—they spend more time browsing, scanning and hunting for keywords compared with people reading on paper and are more likely to read a document once and only once.

When reading on screens, individuals seem less inclined to engage in what psychologists call metacognitive learning regulation—setting specific goals, rereading difficult sections and checking how much one has understood along the way. In a 2011 experiment at the Technion–Israel Institute of Technology, college students took multiple-choice exams about expository texts either on computers or on paper. Researchers limited half the volunteers to a meager seven minutes of study time; the other half could review the text for as long as they liked. When under pressure to read quickly, students using computers and paper performed equally well. When managing their own study time, however, volunteers using paper scored about 10 percentage points higher. Presumably, students using paper approached the exam

with a more studious attitude than their screen-reading peers and more effectively directed their attention and working memory.

Even when studies find few differences in reading comprehension between screens and paper, screen readers may not remember a text as thoroughly in the long run. In a 2003 study Kate Garland, then at the University of Leicester in England, and her team asked 50 British college students to read documents from an introductory economics course either on a computer monitor or in a spiral-bound booklet. After 20 minutes of reading, Garland and her colleagues quizzed the students. Participants scored equally well regardless of the medium but differed in how they remembered the information.

Psychologists distinguish between remembering something—a relatively weak form of memory in which someone recalls a piece of information, along with contextual details, such as where and when one learned it—and knowing something: a stronger form of memory defined as certainty that something is true. While taking the quiz, Garland's volunteers marked both their answer and whether they "remembered" or "knew" the answer. Students who had read study material on a screen relied much more on remembering than on knowing, whereas students who read on paper depended equally on the two forms of memory. Garland and her colleagues think that students who read on paper learned the study material more thoroughly more quickly; they did not have to spend a lot of time searching their mind for information from the text—they often just knew the answers.

Perhaps any discrepancies in reading comprehension between paper and screens will shrink as people's attitudes continue to change. Maybe the star of *A Magazine Is an iPad That Does Not Work* will grow up without the subtle bias against screens that seems to lurk among older generations. The latest research suggests, however, that substituting screens for paper at an early age has disadvantages that we should not write off so easily. A 2012 study at the Joan Ganz Cooney Center in New York City recruited 32 pairs of parents and three- to six-year-old children. Kids remembered more details from stories they read on paper than ones they read in e-books enhanced with interactive animations, videos and games. These bells and whistles deflected attention away from the narrative toward the device itself. In a follow-up survey of 1,226 parents, the majority reported that they and their children prefer print books over e-

books when reading together.

Nearly identical results followed two studies, described this past September in *Mind, Brain, and Education*, by Julia Parrish-Morris, now at the University of Pennsylvania, and her colleagues. When reading paper books to their three- and five-year-old children, parents helpfully related the story to their child's life. But when reading a then popular electric console book with sound effects, parents frequently had to interrupt their usual "dialogic reading" to stop the child from fiddling with buttons and losing track of the narrative. Such distractions ultimately prevented the three-year-olds from understanding even the gist of the stories, but all the children followed the stories in paper books just fine.

Such preliminary research on early readers underscores a quality of paper that may be its greatest strength as a reading medium: its modesty. Admittedly, digital texts offer clear advantages in many different situations. When one is researching under deadline, the convenience of quickly accessing hundreds of keyword-searchable online documents vastly outweighs the benefits in comprehension and retention that come with dutifully locating and rifling through paper books one at a time in a library. And for people with poor vision, adjustable font size and the sharp contrast of an LCD screen are godsends. Yet paper, unlike screens, rarely calls attention to itself or shifts focus away from the text. Because of its simplicity, paper is "a still point, an anchor for the consciousness," as William Powers writes in his 2006 essay "Hamlet's Blackberry: Why Paper Is Eternal." People consistently report that when they really want to focus on a text, they read it on paper. In a 2011 survey of graduate students at National Taiwan University, the majority reported browsing a few paragraphs of an item online before printing out the whole text for more in-depth reading. And in a 2003 survey at the National Autonomous University of Mexico, nearly 80 percent of 687 students preferred to read text on paper rather than on a screen to "understand it with clarity."

Beyond pragmatic considerations, the way we feel about a paper book or an e-reader—and the way it feels in our hands—also determines whether we buy a best-selling book in hardcover at a local bookstore or download it from Amazon. Surveys and consumer reports suggest that the sensory aspects of reading on paper matter to people more than one might assume: the

feel of paper and ink; the option to smooth or fold a page with one's fingers; the distinctive sound a page makes when turned. So far digital texts have not satisfyingly replicated such sensations. Paper books also have an immediately discernible size, shape and weight. We might refer to a hardcover edition of Leo Tolstoy's *War and Peace* as a “hefty tome” or to a paperback of Joseph Conrad's *Heart of Darkness* as a “slim volume.” In contrast, although a digital text has a length that may be represented with a scroll or progress bar, it has no obvious shape or thickness. An e-reader always weighs the same, regardless of whether you are reading Marcel Proust's magnum opus or one of Ernest Hemingway's short stories. Some researchers have found that these discrepancies create enough so-called haptic dissonance to dissuade some people from using e-readers.

To amend this sensory incongruity, many designers have worked hard to make the e-reader or tablet experience as close to reading on paper as possible. E-ink resembles typical chemical ink, and the simple layout of the Kindle's screen looks remarkably like a page in a paper book. Likewise, Apple's iBooks app attempts to simulate somewhat realistic page turning. So far such gestures have been more aesthetic than pragmatic. E-books still prevent people from quickly scanning ahead on a whim or easily flipping to a previous chapter when a sentence surfaces a memory of something they read earlier.

Some digital innovators are not confining themselves to imitations of paper books. Instead they are evolving screen-based reading into something else entirely. Scrolling may not be the ideal way to navigate a text as long and dense as Herman Melville's *Moby Dick*, but the *New York Times*, the *Washington Post*, ESPN and other media outlets have created beautiful, highly visual articles that could not appear in print because they blend text with movies and embedded sound clips and depend entirely on scrolling to create a cinematic experience. Robin Sloan has pioneered the tap essay, which relies on physical interaction to set the pace and tone, unveiling new words, sentences and images only when someone taps a phone or a tablet's touch screen. And some writers are pairing up with computer programmers to produce ever more sophisticated interactive fiction and nonfiction in which one's choices determine what one reads, hears and sees next.

When it comes to intensively reading long pieces of unembellished text, paper and ink may

still have the advantage. But plain text is not the only way to read.