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PEER-REVIEWED JOURNAL ON THE INTERNET

Reading revolutions: Online digital text and implications for reading in academe

by Barry W. Cull

Abstract

While the Internet is a text–saturated world, reading online screens tends to be significantly different from reading printed text. This review essay examines literature from a variety of disciplines on the technological, social, behavioural, and neuroscientific impacts that the Internet is having on the practice of reading. A particular focus is given to the reading behaviour of emerging university students, especially within Canada and the United States. A brief overview is provided of the recent transformation of academic libraries into providers of online digital text in addition to printed books and other materials, before looking at research on college students' preferences for print and digital text, and the cognitive neuroscience of reading on screen.

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Introduction

"Is Google making us stupid?" [1] "Online, r u really reading?" [2] *The dumbest generation* [3]. *Distracted* [4]. Popular book and article titles critical of the Internet, including the Internet's impact on reading, have proliferated in recent years. With all of the recent negative press, it may be easy to overlook the fact that the Internet is a tool of a literate society, that it represents the achievement of literacy. While the Internet is often conceived of in terms of the

transmission of images, video, and music, it remains largely a vehicle for the communication of textual information. The Internet is a text–saturated world. It could only have succeeded in a highly literate society.

Yet thanks to the Internet and its medium of digital text accessed via personal computing devices, most people are reading very differently today than they were in the very recent past. While print may not be dead, literate people across societies throughout the world are reading digital screens on a regular basis. And all readers, including expert readers —such as university students and scholars — tend to read online digital text differently than the printed word.

Since readers are very familiar with reading — we do it every day in many aspects of our lives — it is often taken for granted. It is easy to forget how crucial reading continues to be to the formation and communication of human knowledge. It is central to the operation of modern society. However, because reading is so important, a seemingly small change is likely to have profound ramifications. Far from a small development, online digital text represents a revolution in human learning and communication that we are only beginning to understand. The significant and widespread change brought about by online digital text has taken place very quickly. Although integral to human communication today, the Internet, as we now know it, began less than two decades ago; networked computers did not exist before the first experiments in 1969 [5].

Popular technology writer Nicholas Carr recently suggested that we are at a turning point in the history of modern literate society as books and book reading are in their "cultural twilight" [6]. Robert Darnton, historian and Director of the Harvard University Library, has stated that readers today "feel the ground shifting beneath their feet, tipping toward a new era that will be determined by innovations in technology" [7]. "The explosion of modes of communication," Darnton asserted, "is as revolutionary as the invention of printing with movable type" [8].

Indeed, we are seeing extensive changes in human communication — a nexus of revolutions with profound technological, societal, behavioural, and even neurological facets. The cognitive neuroscientist Maryanne Wolf (2008) has suggested that we are experiencing a shift from the *reading* brain, which has been a hallmark of the human species for millennia, to the *digital* brain.

In this interdisciplinary review article I define reading broadly. It includes what the sociology of reading scholar Wendy Griswold (2008) has called Reading with a capital "R" — any kind of sustained reading for pleasure or information in one's leisure time. But my definition of reading also includes the reflective and critical expert reading for study and work that is associated with individuals such as university students and academics (Hillesund, 2010).

Both types of reading are similar in that they are sustained and in–depth, whether they involve intensely following a narrative or closely analyzing a text. Both differ from the cursory reading we do every day as we make our way through a text–saturated world — reading traffic signs, billboards, food labels, school memos, news Web sites, e–mail messages, tweets, or text messages. Like these examples of cursory reading, in–depth reading can also take place with printed or digital text, but as this review essay will demonstrate, it is a contemplative cognitive activity somewhat at odds with the Internet's zeitgeist of immediacy.

After providing some historical context via a brief overview of the social history of reading, I will look at current reading trends within the general population of North America. I will then look at trends in Internet use as well as online research and reading behaviour, mainly within Canada and the United States, with a particular focus on current and future university students. Then I will examine trends surrounding academic libraries and digital text, and will take a brief look at emerging research on student preferences concerning printed versus digital text. Next, I will draw together relevant research literature from the field of cognitive neuroscience with respect to reading on screen and online. Finally, I will conclude with some general suggestions for university teachers based upon all the literature reviewed.

As part of this review, I will include excerpts of personal in–depth interviews recently conducted with three relevant academic experts, whose published work I have already cited: historian Robert Darnton, Harvard University Library Director; sociology and comparative literature scholar Wendy Griswold, Bergen Evans Professor of Humanities at Northwestern University; and, cognitive neuroscientist Maryanne Wolf, Tufts Center for Reading and Language Research Director.

A very brief historical overview of reading

Reading is not a natural act, or as Maryanne Wolf (2008) explained it, there are no reading genes. Rather, reading is a cultural activity that has undergone profound changes since its inception. In the standard history of reading entitled *Orality and literacy*, Walter Ong (2008) pointed out that the earliest basic script dates from only about 6,000 years ago. Furthermore, the first full alphabet did not have its beginning until the Greeks developed their alphabet about 750 B.C. Putting this time frame into an individual perspective, Wolf poetically wrote that “despite the fact that it took our ancestors about 2,000 years to develop an alphabetic code, children are regularly expected to crack this code in about 2,000 days” [9].

Providing insight into the cultural history of reading, Robert Darnton pointed out that up until the third or fourth century A.D., Europeans “had to unroll a book to read it” [10]. Scrolls would eventually evolve into folded pages, which in turn eventually became gathered pages — or the codex — the book as it is recognized today. The popular writer Alberto Manguel has written that early Christians adopted the codex because they found it a convenient format for keeping their spiritual texts hidden from Roman authorities [11]. These early Christians were the forefathers of the men who later read and transcribed their religious texts in monasteries.

Interestingly, these early scribes first did their work by reading out loud to themselves. Not until the ninth century did monastic regulations begin requiring silent reading [12]. By the thirteenth century the practice of men reading silently and alone became commonplace. This shift to silent reading was a profound change, one that Darnton suggested “involved a greater mental adjustment than the shift to printed text” [13].

Yet the coming of printed text did represent a substantial social shift. In the middle of the fifteenth century, the German entrepreneur Johann Gutenberg produced his first printed

versions of the Bible using his fantastic invention of movable type. The printing press had been born. However, the printing revolution did not happen overnight:

> For the first half century of its existence, the printed book continued to be an imitation of the manuscript book. No doubt it was read by the same public in the same way. But after 1500 the printed book, pamphlet, broadside, map, and poster reached new kinds of readers and stimulated new kinds of reading. Increasingly standardized in its design, cheaper in its price, and widespread in its distribution, the new book transformed the world. It did not simply supply more information. It provided a mode of understanding, a basic metaphor of making sense of life. [14]

By the eighteenth century Europeans had largely began to switch from reading "intensively" to "extensively" [15]. Darnton has written that this may be an oversimplification, but it does make some general sense, given the emergence of cheaply produced texts, which could be made available to a wider public. Interestingly, with the democratization of the printed text, there was a return to reading aloud. Reading was a solitary silent process only for the educated elite who could afford to buy books. For the rest of the population, as Darnton pointed out, reading was a social activity which "took place in workshops, barns, and taverns" … [and] "while children played, women sewed, and men repaired tools." [16].

In the eighteenth century Gutenberg's invention became commercialized and industrialized. Sociologist Wendy Griswold pointed out that during the height of the Industrial Revolution reading finally became a widespread leisure activity in Europe and North America. And as the post–industrial information society developed, reading became necessary for many occupations in the skilled labour force. Griswold also argued that the past two centuries have been the golden age for leisure reading, and that readers in most societies have usually been a minority:

> Only in a small portion of the world (northwest Europe, North America, and — somewhat later — Japan) and only for a brief period of time (mid–nineteenth to mid–twentieth century) was reading the standard pastime for the middle–class majority. The more typical situation is the one that is increasingly the case today: readers are an elite group that holds disproportionate political, economic, and cultural power. To recognize this as a fact is neither to decry the elitism nor to celebrate the avidity of committed readers, but it is to gain a clearer sense of where the practice of reading stands now and in the foreseeable future. [17]

Current North American reading trends

Five years after an initial study suggesting a substantial decline in reading in the United States, the National Endowment for the Arts (NEA) published its 2009 report, *Reading on the rise*, focusing on literary reading for leisure. The NEA suggested that young Americans aged 18–24 have "undergone a particularly inspiring transformation from a 20 percent decline in 2002 to a 21 percent increase in 2008 — a startling level of change" [18]. Nearly 52 percent of Americans 18–24 years of age, and just over 50 percent of all American adults, read books for pleasure [19]. Canadian teenagers have reported a level of reading similar to that of their slightly older American counterparts. Bibby, *et al.* (2009) reported that 47 percent of Canadian teenagers 15–19 years of age received a "great deal" or "quite a bit" of pleasure from reading.

Young Canadian readers were more likely to be female than male: 56 percent of those who reported pleasure reading were female, while only 35 percent were male [20]. In 2009, the publishing industry reported that men in the United States only accounted for 29 percent of purchases made within the adult fiction market, compared to 40 percent of the U.K. market (Bowker LLC, 2009). The NEA surveys also consistently suggest that more women read than men: about 42 percent of men are voluntary readers of literature (defined as novels, short stories, poems, or plays in print or online), compared to 58 percent of women (National Endowment for the Arts, 2007). However, men have been beginning to read more — the rate of literary reading amongst men is increasing at more than twice the rate that it is for women (National Endowment for the Arts, 2007). Unfortunately the NEA studies do not include in–depth reading for work or school. If this were included, the overall rates and breakdowns by sex might look very different.

While these studies suggest that reading is enjoyed by a substantial number of North Americans, on the flip side, about half of the populations surveyed are not readers. Griswold has suggested that there is a distinct "reading class" emerging in North America and throughout the world. Despite the recent increase in leisure reading in the U.S. as reported by the NEA, Griswold has argued that not everyone will read voluntarily. Griswold instead thinks that a highly educated and affluent elite segment of society is emerging, which actually reads more than the average readers of the past. Griswold has predicted that this reading class — composed of both the young communications elite and older, less technologically advanced long–time committed readers — will remain a distinct minority throughout even the world's most highly educated societies:

> Numerical predictions are hazardous, but I will venture a couple. In the West and Japan, the reading class will stabilize at something between one–quarter and one–third of the population. It will vary — Norway's will remain larger than Italy's — but overall that will be the picture: a minority, but a good–sized minority, of adults will read in their spare time. In developing countries the reading class will be a smaller minority, perhaps around 15 percent. The reading class will remain strong, but the day of the reading culture is over. [21]

While Griswold believes that a widespread reading culture no longer exists, she has suggested that members of the reading class still place an extremely high value on reading. In our interview, she pointed to the "sacredness" of reading within universities:

> University libraries, by their sheer physical nature, tell you something about the value of reading. [They are often located in] a centered place on a campus, often with steps [leading up to their front entrances] and with a hallowed quiet [atmosphere] — which tell you that you are in a sacred space. Universities tend to perpetuate the sacred aura of reading in general and of books in particular, and students pick up on that — even if it is an engineering student who never reads much and never intends to read much. But when they have kids, do they want their kids to be reading? You bet. Universities are part of the reproduction of the prestige and sacred quality that is associated with reading … . [There is an] ideology of reading. Reading is a sacred activity (Griswold, 2009).

The benefits of leisure reading

Part of the high value placed on reading may have something to do with the intellectual benefits of reading, including leisure reading, which has been long established by research. Predictably, the practice of reading helps to strengthen literacy proficiency — the more you read, the better reader you become. A significant co–relation exits between the frequency of reading books and literacy levels (Grenier, *et al.*, 2008). Similarly, youth who read or write letters in their leisure time at home score significantly better on literacy scores [22]. When it comes to college students, students who read for fun as well as for study do better academically than students who do not read beyond what is required for their coursework (Burgess and Jones, 2010). As students move into the work force, a significant loss in literacy skill level can occur over their life, unless they read at home or away from the job (Willms and Murray, 2007).

There are also various noteworthy relationships between literacy rates and positive social behaviour. For example, there is a co–relation between high youth literacy rates and low crime rates, low unemployment and dependence on social welfare, and low health care expenditures [23]. Similarly, high levels of adult literacy are associated with higher levels of employment and wages, lifelong learning activities, participation in society, and level of health [24]. A strong correlation has even been found between literacy levels and the likelihood of time spent in prison (National Endowment for the Arts, 2007). The NEA has found that the 50 percent of Americans who are readers have far higher levels of cultural and civic engagement than non–readers: they visit more museums, see more plays, attend more concerts, play more sports, exercise more, do more outdoor activities, and they are much more likely to volunteer and vote (National Endowment for the Arts, 2007).

A significant co–relation has also been found between library use and social involvement. People who frequent libraries have higher levels of trust, are more likely to be involved in their community, and show a high level of civic engagement (Johnson, 2010).

Internet usage trends

On the other hand, the social benefits of the Internet are an ongoing matter of dispute. Robert Putman, political scientist and author of *Bowling alone*, first blamed the Internet for the decline of social capital, but then a few years later suggested that an involvement in online communities could lead to greater social engagement (Putnam, 2000; Putnam, *et al.*, 2004). The research of health scientists continues to show a negative relationship between the Internet and social capital, while social scientists have suggested a positive relationship between the two (Richards, *et al.*, 2010; Shah, *et al.*, 2001; Wellman, *et al.*, 2001).

While research findings are divided concerning the social benefits of Internet use, people around the globe have widely adopted online communication. Worldwide access to the Internet reached 26 percent in 2009, while usage of cellular phones — which increasing provide Internet access — reached 67 percent of the entire world's population (International Telecommunication Union, 2010).

Younger people tend to be heavy Internet and cell phone users. The example of Canadian youth provides an interesting case study. In 2008, 98 percent of Canadian high school students aged 15 to 19 were using computers one hour a day or more (Bibby, *et al.*, 2009). About one half of those teenagers were using their computers at least two hours a day, while another 20 percent were on their computers for three to four hours, and 20 percent used their computers five hours or more each day [25]. More recently it has been reported that 18–34 year old Canadians are spending an average of 20 hours a week online (Ipsos, 2010). When it comes to phones, 71 percent of Canadian households have reported having a cellular phone for personal use [26]. For 95 percent of those households, 13–17 year–olds are the main household phone user [27].

Yet all this time spent online does not mean that young people have given up the practice of sustained reading. In fact, people who are online also tend to be readers. The amount of time students spend on the Internet has not been found to interfere with the time they report spending on reading for their studies or for leisure [28]. Griswold and Wright (2004) found such a positive co–relation between Internet use and reading, and commented on the double advantage enjoyed by readers who use the Internet:

> People who exhibit the more–more pattern, reading a lot and using the Internet a lot, are doubly advantaged. They possess information, social connections, and cultural capital, and they know how to get more when they need them … .The Internet is not going to displace reading but it is going to give readers yet one more advantage. [29]

In 2008 the NEA concluded a similar thing, suggesting that 84 percent of adults who read literature (defined as fiction, poetry, or drama) either directly online or downloaded from the Internet, also read books [30]. A Canadian study using the Statistics Canada 2005 General Social Survey found that both heavy and moderate Internet users spend more time reading books than people who do not use the Internet, although people in all three categories of Internet usage read similar numbers of magazines and newspapers [31].

Online research and reading behaviour

However, spending time online does not automatically lead to the development of online research or advanced reading skills. Sociological research of the digital divide has suggested online research skills are often not well developed among people who are online (Hargittai, 2002). When it comes to university students, especially beginning undergraduates, they are typically content to make do with simplistic "good enough" information search strategies — ease of access to information often continues to be more important than the accuracy of that information (Currie, *et al.*, 2010; De Rosa, *et al.*, 2006; Nicholas, *et al.*, 2009; Weiler, 2005). There is a relationship between this low level of information literacy skill and academic performance — low–performing students typically have low information literacy skills [32].

This path–of–least–resistance research behaviour is not distinctive only of students. Within academe, everyone — from first–year undergraduates, to practitioners, to professors — are exhibiting a similar tendency to search "horizontally" instead of "vertically," skimming information and bouncing quickly from place to place:

> The average times that users spend on e–book and e–journal sites are very short: typically four and eight minutes respectively. It is clear that users are not reading online in the traditional sense, indeed there are signs that new forms of "reading" are emerging as users "power browse" horizontally through titles, contents pages and abstracts going for quick wins. It almost seems that they go online to avoid reading in the traditional sense. [33]

Indeed, Web site designers know very well that people generally do not read much online. Web site users tend to browse pages rapidly, and read only about 20 percent of the text on an average page (Nielsen, 2008; Weinreich, *et al.*, 2008).

A typical "screen–based reading behaviour" is emerging, characterized by more time spent on "browsing and scanning, keyword spotting, one–time reading, non–linear reading, and reading more selectively", while less time is spent on in–depth reading, and concentrated reading [34]. When online, people switch between two poor kinds of reading — "tunnel vision" reading in which one reads a single bit of text without a sense of the context, and "marginal distraction", which happens, for example, when a person reads textual feeds on the sidebar of a Web site such as a blog (A. Liu, *et al.*, 2009).

Yet it is an over–simplification to suggest that this sort of bouncing happens exclusively online. A recent study of academic staff at one university suggests that the "immersive reflective" reading done by these expert scholars is typically discontinuous even when done on paper:

> Experts seldom read a scholarly article or book from beginning to end, but rather in parts, and certainly out of order, actively using hands and fingers in flicking back and forth, underlining and annotating, often connecting their reading to their writing, and usually spreading pieces of paper around their desk (Hillesund, 2010).

Online digital text: The story of academic libraries

The story of modern research libraries offers a useful example of how profoundly the technological context of academic reading has recently changed. For several millennia, right up until just two decades ago, the central role of a library was to collect and house physical texts: from clay tablets, to scrolls, to printed books (Battles, 2003; Manguel, 2006). While printed text remains essential to most academic libraries, today's libraries have also become a core conduit via which researchers access scholarly texts online. Just within the last few years, Canadian academic libraries, in a situation similar to libraries throughout the Western world, have reached an interesting tipping point — librarians now spend the majority of their collections budgets on electronic instead of printed texts (Canadian Association of College and University Libraries [CACUL] Task Force on Standards in Higher Education, 2010; Canadian Association of Research Libraries, 2008).

Libraries are convinced that digital text, now in its infancy, is likely to have a long future. Not only do they purchase electronic texts, but most academic libraries have also become publishers of electronic texts, whether they are digitizing large portions of their book holdings, or focusing on scanning a relatively small number of archival documents from their unique special collections. This shift to digital "holdings" has brought tremendous benefits to university researchers, students, and the general public. However, the reason for this shift has also been economic, having to do with escalating prices for journal subscriptions and limited library budgets (Darnton, 2010).

Academic libraries first started to take e–journals seriously back in the 1990s when they began to purchase databases of full–text articles provided by aggregator companies. The cost per article was vastly cheaper than the cost of articles within many individual academic journals, subscriptions to which had begun to skyrocket. Furthermore, the e–journal article, with its relatively short length and focus on newly emerging research, quickly proved to be ideally suited to the digital format. Time–sensitive current research articles could be delivered to researchers' electronic desktops much quicker than they could be printed on paper and shipped to the library or a physical desktop.

Within the last decade, several information technology changes have coalesced to make e–journal purchases increasingly more and more popular. Most academic journal publishers now directly provide their own digital editions of their journals — allowing libraries to bypass the image quality and access problems which were sometimes experienced when dealing with third–party aggregators. In addition, increasing Internet bandwidth has helped improve access speeds, high–quality colour laser printers have become more common, while high–quality LCD screens are now standard. All of this has made both end–user printing and on–screen viewing practical and convenient. In Canada, two rounds of national site–licensing programs have also made it financially feasible for many small universities to gain access to enormous high–quality academic e–journal collections, research databases, and other significant electronic resources for the first time (Canadian Research Knowledge Network, 2010).

Popular e–books

Academic libraries have also provided access to collections of electronic monographs for several years now. However, poor e–book interfaces, along with various cumbersome publisher–imposed access restrictions, have helped to make e–books unpopular with libraries and library users (Berg, *et al.*, 2010; Coyle, 2008; Lynch, 2001). For example, an analytical online activity equivalent to underlining and highlighting text on paper has not yet become popular, even though e–books typically have these features. For many readers, the technology of print on paper continues to be more suited to analytical in–depth reading than e–books on computer displays.

Yet recently a new wave of considerable discussion of e–books and e–book readers has been taking place in the popular press and online, as companies have begun to successfully market popular e–books directly to consumers (Tonkin, 2010). Apple's iPad tablet computer is competing with dedicated e–book devices that use e–ink such as Amazon's Kindle, Sony's Reader, Barnes & Noble's NOOK, and Indigo/Chapters/Borders' Kobo. E–books have finally started to experience some commercial success (International Digital Publishing Forum, 2010). There is some indication that many of the early adopters of dedicated e–reader devices have been consumers over the age of 50 or between the ages of 18 and 34, although more of the people in the younger category have preferred multiple–purpose devices (Gallagher, 2009).

When it comes to multi–purpose portable devices, the personal computing industry has predicted that sales of tablets such as the iPad will undergo enormous growth over the next few years (Paczkowski, 2010). It is noteworthy that the highest–selling e–reading device is not a dedicated e–book reader. When Apple was rumoured to be working on an e–book reader a few years ago, CEO Steve Jobs expressed his lack of interest: "It doesn't matter how good or bad the product is, the fact is that people don't read anymore," he reportedly said, continuing by stating that "40 percent of the people in the U.S. read one book or less last year. The whole conception is flawed at the top because people don't read anymore" (Markoff, 2008). Nicholas Carr (2010) has summed up Apple's involvement in the tablet phenomenon this way: "Jobs is no dummy. As a text delivery system, the iPad is perfectly suited to readers who don't read anymore".

When it comes to direct–to–consumer content for e–book readers, Amazon, Apple, Indigo/Chapters, Barnes & Noble, Borders and others have already developed large collections of electronic books, and Google may become the largest content seller, offering its content without any proprietary hardware or format restrictions as part of Google eBooks. As part of its other longstanding and controversial service, Google Books, Google has partnered with academic and other libraries in the U.S. and around the world since 2004 in order to scan print books in their collections. Google has also signed contracts with publishers across the globe to include new "born digital" books which, given the copyright restrictions on some of the library scanned books, will likely be the main content sold via the Google e–bookstore.

Thanks to Google Books & eBooks and other noteworthy major digital book initiatives such as HathiTrust and the Internet Archive, as well the increasing popularity of e–book readers and tablet computers that include e–book applications, students entering university may soon be as comfortable with the notion of e–books as they are with print books:

> Most undergraduates, 10 years from now, or five years from now, will perhaps go to Google Books first. You locate something by looking it up in Google. That will be a first impulse on the part of students. Here at Harvard the Google link goes right into our catalogue. So the student can begin with Google, but wind up in the catalogue — sometimes even in the library (Darnton, 2009b).

In fact, it has already been found that 89 percent of college students use search engines to begin an information search while only two percent start from a library Web site (De Rosa, *et al.*, 2006). For several years now, academic librarians have been in the business of teaching students to dig deeper — to go beyond Google in order to get to the academic content supplied by the library, whether online or in print.

Student preferences for reading print vs. digital text

While university students operate in a world immersed in digital text, they have not simultaneously abandoned print. It is not true, as Steve Jobs stated and as Nicholas Carr implied, that they like the iPad because they don't read. In fact, for their university studies, students prefer to read on paper, although they also want the convenience of online digital text. Liu has found that graduate academic library users like the access provided by online electronic resources, but prefer to print the electronic documents in order to read them (Z. Liu, 2006). In a study of students at the Universidad Nacional Autónoma de México (UNAM), the majority of students preferred print, and 63 percent reported that they could bear reading a document on a computer screen for no more than one hour (Ramírez Leyva, 2003). When it comes to course textbooks, a marked student preference for paper over e–books has recently been found (Woody, 2010).

Meanwhile, in a recent survey of students at a university in China, an interesting gender imbalance was found in the paper/electronic preference: 73 percent of the female students prefer print, while only 51 percent of male students prefer print (Z. Liu and Huang, 2008). More research will be needed in this area as emerging members of the "Google generation" — students born since 1993 when graphical Web browsing first appeared — go through the post–secondary education system.

The cognitive neuroscience of reading

While reading has historical, technological, social, and behavioural contexts, it is obviously also a cognitive and neurological activity. Therefore it is reasonable to conclude that the practice of reading digital text is likely to have some neurological implications. While much is still unknown about the human brain, one accepted neuro–scientific fact is that the structure and function of the human brain changes as a result of internal and external stimulation (Doidge, 2007). Functional magnetic resonance imaging (fMRI) can literally show a picture of the brain changing in developing readers (Poldrack and Sandak, 2004; Yarkoni, *et al.*, 2008).

While reading has changed the brain, there is a limit to such cerebral plasticity. As cognitive neuroscientist Stanislas Dehaene (2009) notes, the brain did not evolve for culture, but culture evolved to be learnable by the brain. Through history all writing systems have shared common traits — they tend to be a series of strokes that the brain can be trained to readily interpret. And so over the millennia that humans have been reading, reading technologies have evolved from strokes on clay, to scrolls, to modern–day printed books, in order to meet the limited adaptability of the brain.

The way the brain is adapting to meet the new medium of electronic text is only beginning to become understood. Despite the fact that skimming and jumping around from place to place within text is not limited to online reading, this type of reading appears to be the most common type of reading online. Popular writers, such as Nicholas Carr (2010), continue to express concern over its potential neurological affects.

Indeed, in recent years researchers have called attention to the substantial differences between reading on screens online and in print, and have been calling for more recognition among educators about the cognitive differences between the two types of reading (Burke and Rowsell, 2008; Leu, *et al.*, 2008; Mokhtari, *et al.*, 2009). While there is not yet enough published scientific research to make many definite conclusions about the effect of online reading on learning and the brain, it is known that the process of reading on screen tends to be cognitively different from the process of reading on paper, in terms of brain activation, the contextual environment, cognitive focus, comprehension, and reading speed.

Brain activation

Searching the Internet on a topic stimulates more neural circuitry than reading about the topic in a linear e–book (Small, *et al.*, 2009). While it is true that searching for information and reading that information are two different activities and therefore difficult to compare, it has

specifically been shown that online reading is a more "cognitively complex" process than reading in print due to the phenomenon of hyperlinking (Coiro and Dobler, 2007). Linear reading and hypertextual reading are cognitively very different from each other. Essentially, the conclusion is that the choices offered to the reader by online hyperlinks require more mental decisions to be made, and thus require the use of more cerebral "real estate."

For example, readers use more cognitive effort when reading an online news story that was selected from a wide array of stories (Wise, *et al.*, 2008). Just like their printed counterparts, news Web sites are more likely to get their readers to invest more energy in reading a story if they were stimulated with many story choices on the first page. It has also been found that scrolling on a screen requires more mental workload than reading Web sites that do not require scrolling (Wästlund, *et al.*, 2008).

The *context* is the message

Another aspect of the cognitive difference between reading on screen and on paper has to do with the context provided by each reading medium. Robert Darnton describes how the literary critics' notion of the "paratext" — the framework of a text — affects the meaning that a reader derives from that text. Just as a book's cover, dedication, and acknowledgements make a "frame" that shapes a reader's interpretation of a book's main text, the paratextual elements of online text are important. In our interview, Darnton spoke about his own personal interaction with the paratext of print newspapers, comparing this to the paratext of on screen reading:

> I used to be a reporter for the *New York Times* and so I am very attached to the paper version of it. But it's not simply that. I think older readers are used to looking at Page One and treating it as what I call a map of yesterday — the way it is organized by the *Times* is telling you what was most important. There are all kinds of typographical signs: The nature of the headline, if the story is on the right hand side (which indicates it is more important than if it is on the left hand side or below the fold), etc. … When that paratextual context drops away through texts appearing on machines, what is lost is a kind reading … Of course, on a machine there is a different kind of paratext. The paratextual ingredients to reading on a hand–held device or a computer are very different (Darnton, 2009b).

Research on e–book readers has suggested that the physical paratext of the device itself has an influence on the sensations that people may feel while reading on the device, and subsequently on their interpretation of the text. Participants in one study were more likely to perceive humour in the text when reading on a device that was "happy, light and clear" [35]. In a very concrete way, it appears that the medium truly is the message, as Marshall McLuhan (1964) first articulated nearly a half–century ago. It remains to be seen how the evolution of our computers will effect the way we interpret the text we read on their screens. It is interesting to note that many of the cases and covers for the new e–book readers and tablet computers on the market mimic the covers of beautifully bound printed books.

Cognitive focus and multitasking

Nicholas Carr has suggested that the focused reading that used to come naturally in the print world has not been transferred to his own personal reading on screen: "Once I was a scuba diver in the sea of words," he analogizes, but "now I zip along the surface like a guy on a Jet Ski." [36]. As was mentioned previously, this type of textual scanning is typical behaviour for people online (Rowlands, *et al.*, 2008). When working with digital information people also switch activities every three to 10 minutes, pointing to an obvious conclusion: "It is just not possible to engage in deep thought about a topic when we're switching so rapidly" (A. Liu, *et al.*, 2009).

This online multitasking and lack of cognitive focus is not an effective way to learn. Evidence suggests that multitaskers find cognitive focus difficult, that it takes longer to do two tasks simultaneously than it does to complete the same tasks one after the other, and that knowledge gained in dual–task situations can be applied less flexibly in new situations (Ophir, *et al.*, 2009; Rubinstein, *et al.*, 2001; Foerde, *et al.*, 2006).

Comprehension, speed, and addiction

When it comes to comprehension, it may be easier to understand text in print, although that conclusion is not certain. Early research found that comprehension levels were lower on screen, however in more recent years the comprehension gap between reading on a screen versus on paper has been decreasing. It has been suggested that speed reading and browsing —typical online reading behaviour — results in an overall decline in the level of comprehension (Dyson and Haselgrove, 2000).

With respect to speed, in the early 1990s, Dillon (1992) found that reading was 20–30 percent slower on a screen than on paper. More recent research continues to suggest that reading on paper continues to be faster, although some studies have begun finding no significant difference between the two (Noyes and Garland, 2008).

Meanwhile, as the personal computer has shrunk to the size of a hand-held device, questions are emerging about the psychological effects of the constant connection users have to their communication devices. Internet addiction has become accepted as a psychological and medical disorder, and it includes an addiction to reading, writing, and sending of e–mail messages, as well as cell phone texting (Block, 2008; Frank, 2010; Small and Vorgan, 2008).

Even though many people spend their lives with their digital devices always on, most will not develop a clinical addiction. However the full educational ramifications of this constant Internet connection are not yet known. Many university students study, attend lectures, commute to campus, all while never turning off their Internet cell phones, laptops, or tablet computers. Will this near–constant access to information interfere with students' desire to comprehend and remember information, necessary to the educational process of turning it into knowledge? Author and university business school lecturer Don Tapscott recently suggested that students "might not have to stress about the details — those you can check" [37]. On the other hand, Maryanne Wolf has wondered if there is an emerging "society of decoders of information, whose false sense of knowing distracts from a deeper development of … intellectual potential" [38].

"Time to think beyond"

Most of the ways in which reading online tends to be cognitively different from reading print has to do with time — the time that is typically taken for sustained thought when reading on paper, versus the time required to skim and scan text, which may happen when reading print, but is especially typical of reading online. Maryanne Wolf pointed out that "the mysterious, invisible gift of time to think beyond is the reading brain's greatest achievement":

> The brain's design made reading possible, and reading's design changed the brain in multiple, critical, still evolving ways … . By its ability to become virtually automatic, literacy allowed the individual reader to give less time to initial decoding processes and to allocate more cognitive time and ultimately more cortical space to the deeper analysis of recorded thought … . A system that can become streamlined through specialization and automaticity has more time to think. This is the miraculous gift of the reading brain … . Few inventions ever did more to prepare the brain and pose the species for its own advancement [39]

In contrast to the benefits of time within the context of traditional print literacy, during our interview, Wolf speculated on a potential result of superficial digital literacy on students' motivation to learn:

> I am worried about kids who are immersed in digital culture. They will get to college and they will have been Twittering so much that they won't have the patience to read those really long cognitively convoluted and complex sentences. They may not have developed those rich networks which are required in order to read at a high level of sophistication. … The effort is what we are going to lose. They are becoming not so much a lazy reader, but an atrophied reader (Wolf, 2009).

Wolf also pointed out another time–related concept about reading and the brain — the speed with which the print to digital revolution has taken place, compared to the slow pace of change in writing systems of the past:

> If we look at history in terms of the Sumerian and Akkadian writing systems, one lasted about 1,500 years. The Sumerian scribes and the Akkadian scribes sat side by side and maintained both. There was a long period in which the best of one could be incorporated within the other. … over a millennium they were being simultaneously taught. We have no such moment. We are doing what no internal university review board would ever allow. As a society we are going beyond anybody's knowledge, and just doing it. We are lurching into a whole new culture, and we don't know

what that is going to do to the young brain (Wolf, 2009).

Discussion and conclusion

Over the millennia, reading has changed alongside us, and it has also changed us. Reading is a cultural activity that has changed over time, but that has also physiologically changed the brain. This evolution has brought us to what popular technology and neuroscience author Jonah Lehrer (2009) has called a "perfect cultural product" — the book we continue to hold on to today. And it is also now bringing us into the revolutionary new world of online digital text.

Yet the book — and print on paper in general — is far from dead. It has survived predictions of its imminent demise for many, many years, long before the current generation of information technology business leaders' predictions to that effect (Uzanne, 1894). It is worthwhile to remember that new technologies often do not supplant older proven technologies that accomplish a similar task. For example, Internet video streaming did not replace television, which did not replace radio before that. Print appears likely to remain alive for the foreseeable future, especially among some specific social groups, such as students within the reading class. University students have not left behind the reading of print, even as they have become immersed in online text.

It remains to be seen whether or not the very different process of reading on screen and online will lead to students who are, as Maryanne Wolf has predicted, atrophied readers of print. Wolf (2009) has suggested that more research is needed to show what the young brain is doing during reading. "Are students activating as much of their brains as you and I activate when we read?" she wondered, continuing that "we do not know any of that — we need longitudinal research." Indeed, ongoing research is needed on many aspects of the evolving reading habits of students over the coming years, as we continue to experience the revolutionary technological, behavioural, societal, and neurological aspects of online reading.

In his discussion of the "lost art of reading," David Ulin (2009) wrote of the Internet's "illusion that illumination is based upon speed." Today we have immediate access to more recorded information than ever before in history. However, assuming that we desire knowledge to be housed in the human brain as well as inside technological gadgets and data store clouds, it must always be remembered that accessing information and the acquisition of knowledge are two different phenomena. Information access does not equal knowledge gained. Thanks to our information technology, the former is becoming relatively easy, while the latter continues to be difficult. It continues to take time. The power of reading, whether of print or online text, continues to lie in this power of time — time to digest words, time to read between the lines, time to reflect on ideas, and time to think beyond one's self, one's place, and one's time in the pursuit of knowledge.

The reading trends discussed in this essay have several implications for all levels of education, and for academe in particular. University educators are well aware of the Internet's pervasive illusion of instantaneous knowledge. In a world influenced by a powerful

online culture, we must remain committed to motivating our students to take the time required for in–depth reading. Independent learning, which continues to be based on in–depth reading, will always take time.

In addition, learning how to learn is also a process that takes time. Professors, librarians, and other academic faculty who teach young emerging generations of students need to always remain cognizant of the fact that information literacy and advanced intensive reading skills grow throughout a student's educational career. And these skills continue to be important after graduation. Therefore we may need to remind ourselves of the importance of teaching transferable critical reading skills, and the value of motivating our students to remain lifelong learners who practice the skill of in–depth reading throughout their lives, no matter where our information technologies may take them in the future.

Furthermore, while continuing to provide the necessary access to digital text, academic administrators and librarians need to be aware of students' continued desire to read from print, as well as their need for the availability of appropriate spaces — such as library reading rooms and study halls — suitable to the time–dependent and cognitively intensive activity of deep reading, whether it is done on paper or on a screen. Though perhaps taken for granted by many readers, educators cannot afford to forget the continuing centrality of reading — with all its technological, behavioural, and neurological facets — both inside our campuses and in the wider societies in which we live.

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