Figuring Out What the Internet is Doing to Our Brains

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Introduction

It has been six years since an international angst regarding the internet's dark side reached a peak with the widely-discussed 2008 article "Is Google Making Us Stupid?" in which Nicholas Carr declared, "Over the past few years I've had an uncomfortable sense that someone, or something, has been tinkering with my brain, remapping the neural circuitry, reprogramming the memory" (Carr, 2008). Although he was not the first to remark on the down side of instant access to information, the article quickly threw him into the spotlight, making him the de facto spokesperson for a new and growing concern. Carr explains the problem as this:

> "Immersing myself in a book or a lengthy article used to be easy… Now my concentration often starts to drift after two or three pages. I get fidgety, lose the thread, begin looking for something else to do… The deep reading that used to come naturally has become a struggle." (2008).

After 10 years of using the internet regularly, Carr felt that he had become more susceptible to distraction than he used to be, and this was preventing him from reading longer pieces and from thinking deeply about what he does read; he even claims it is also eroding his ability to think deeply in general, that this is happening on a neurological level, and that the effect is permanent. Along with many others, I became interested in finding out if this is really true, and if not, then why had so many people been so quick to agree with him. My first thought was that Carr had tapped into a collective but unfounded and irrational fear.

My Own Experience

On one level, I could relate to what Carr and others were describing: I had also noticed that I would struggle to read books the way I once had done. However, I was not an avid or frequent internet user at the time I first noticed the problem, so I attributed the change to my age, the increasing commitments and complexity of my own life, and the increasing pace and complexity of modern life in general. I had been living in Japan for several years and was feeling the first signs of age as my high-speed young adulthood eased into the plodding second-gear of my mid-thirties.

In the previous 15 years, I had packed up and moved to a make a new home for myself a dozen times – a dozen different addresses – in three U.S. States and a foreign country on the opposite side of the globe. I had had three serious relationships, all of which had ended painfully. I'd had a six-year stint in the Army Reserves, which was bookended neatly by the invasions of Grenada and Panama just prior and just after my years of active reserve duty. I'd finished two university degrees, learned to drive (car and motorcycle) and purchased my first vehicles, including a motorcycle in Japan, at a time when I barely spoke the language. I had worked innumerable jobs in retail and office administration and one floundering 3-week attempt at waiting tables at a local Howard Johnsons. On campus, I had been an interior painter, a ceramic arts studio assistant, a graduate assistant (English composition instructor the first year and a newsletter editor the next). My last summer as a student, I interned as a technical writer. When I graduated, all my hard work paid off and I finally landed a cushy job in the high tech industry, editing computer software documentation. I didn't know that the computer industry was about to transform, that the old behemoths would be outdated in just a few years' time. But I knew something was amiss because within weeks of accepting the job, the company instituted a hiring freeze that would never be lifted.

A year into my new job, I was breaking off my engagement to my college beau at about the same time Iraq invaded Kuwait and the U.S. mobilized troops to the Persian Gulf. My old Army Reserve unit was called up to serve, and I remember sleepless nights in my new apartment, watching the tv news reports of SCUD missiles firing across the night sky, thinking about my friends in my old unit, wondering whether the war would last long enough for me to be called up again, since I was technically still on the books. Fortunately for me, the war was over in a matter of months.

When the Gulf War ended, the U.S. economy slid into recession, making an already dismal and paranoid work environment into a nightmare. I spent the next several years of my career watching first hand as that once-huge and highly-esteemed high-tech company slowly disintegrated, witnessing the anger and anxiety of its complacent but dedicated workforce, many of whom turned inward, in depression, or outward against each other. In five years, I had worked on 18 different software products, only a few of which were ever released. My “most productive years” a wash out, I had no trouble leaving.

At 29-years-old, I moved to Japan, an overwhelmingly exciting but also unexpectedly difficult transition. With each transition, I had said good-bye to innumerable friends, classmates and professors, neighbors and co-workers who had been, in small but significant ways, dear to me. It was hard but also fairly typical for others in my generation. Moving to Japan was something different altogether. The stimulation of a new career and life in a foreign culture was exhilarating, but also mind-numbing, and the separation from my own culture was surreal. Within my first year, I witnessed Japan’s fear and anguish after the Great Hanshin Earthquake, followed quickly by the dismay, shame and anger of the sarin gas attack in Tokyo’s subway. My first two years in Japan, I could barely remember my name, let alone write letters to old friends. In my third year in Japan, the East Asian Economic Crisis hit, causing anxiety and bankruptcies all around. My organization, a small business college with and extension school for non-credit language lessons, was fortunate in that it only underwent general belt-tightening, but these were painful nonetheless, and the budget cuts involved every women in the company losing half her salary.

Living in Japan got easier, and I could eventually enjoy a few years of relative comfort, but as my fluency in Japanese increased, I became aware that I was losing fluency in spoken English. I knew that I would have to leave someday and move back to the U.S. again, a prospect that would only get more difficult the longer I stayed away, all the worse because I knew that I would probably have to transition to a new career as well. The idea of having to retrain for a new career didn't bother me, since labor experts had been telling my generation that we should expect to have three different careers in the course of our lifetime (in contrast to the one that our parents would have had), but I knew it would involve another difficult transition.

It was around this time that I had first noticed issues with reading; I sometimes didn't have the patience to sit and read the way that I once had done, or I was just too tired to read. I wasn't surprised, since I'd been living with low-level stress for my whole adult life, punctuated with brief periods of extreme stress, and only a few, rare periods of relative calm. As my body slowed down and my psyche longed for the familiarity of "home," I started to feel the weight of my exhaustion. The internet had just become a phenomenon, so in 1998, I bought a computer, arranged for internet connection, and soon acquired email addresses for several of my old friends. But the internet was still too cumbersome to present a great temptation and certainly didn't cause any great change in my lifestyle or the rhythm of my day-to-day existence.

A decade later, when Carr's article appeared in *The Atlantic Monthly,* I had moved back to the United States and settled into another new address. The reverse culture shock was far worse than what I'd expected because I'd become so accustomed to life as an expatriate, life in a different culture. I was all the more exhausted, too, having lived in another two countries in the intervening years, another decade of hello's and good-byes, and for most of that time I had also been in the midst of a mysterious illness that wouldn't be diagnosed for yet another few years.

Returning to the U.S., post 9/11 and shortly after the "dot-com bubble" burst and U.S. invasion of Iraq, I was also hit with the full force of all the changes in American society that had happened in the previous 10 years. I remember cringing in shock at the general tone of hostility and combativeness in tv shows, a far cry *Star Trek: The Next Generation* I had been used to watching in the early 90s, much less *The Waltons* and *Happy Days* that I grew up with. I felt constantly pounded by aggressive advertising and marketing that others seemed to take in stride, the degree of lying and deceit that people took as a matter of course. Mortgage lending companies, for example, zeroed in on my good credit rating and, before even landing a real job, I was repeatedly informed that I would "qualify" for a mortgage. As enigmatic and inexplicable as Japanese culture had sometimes seemed, American culture had become, it seemed, utterly insane.

Reading Carr's 2008 article was the first time I became aware of any kind of general concern that the internet was causing an inability to think deeply. Busy with my own major life transitions, I was focused on finishing another Master's degree and getting myself well and truly settled in my third (and hopefully final) career. I was in "survival mode," just trying to get by and get through reverse culture shock, uncomfortable in Boston and the distinctly "corporate" feel of graduate school in the new millennium that was so different from what I expected and what I had experienced in the late 1980s. Instead of an insular, supportive academic atmosphere, students seemed to be treated like statistics in the run for higher college ratings, any kind of relationship with professors or staff was nearly non-existent, as more and more instructors were adjunct (with only limited investment in the success of the program or the students), and graduate students had become the cash cow of the system, propping up unnecessary layers of administration and bureaucracy. Higher education was no longer a process of intellectual development but a consumer product to be manipulated and maximized for higher ROI, while unfortunate professors were caught between their mission to educate and their administrators and students who increasingly operated from a distinctly consumer mindset.

Despite all of that, I was excited to be entering my new profession, Library and Information Science. This was predicted to be an excellent career choice for the coming decades, as the proliferation of information, and information technology, meant an increased need for specialists to manage it. Librarians would be integral, said the experts, in keeping track of all that information, helping others find it and use it most effectively. To top it off, legions of "baby boomers" were expected to retire early. In early 2008, I was looking forward to a bright future.

I first read Carr's article for one of my classes, and I remember being unimpressed. I remember thinking that it was poorly written: his oft-quoted jet-ski metaphor seemed awkward and ill-fitting; his whole argument rested on scanty evidence, and the one or two empirical studies he referenced were pulled out of context and manipulated to imply something completely different than what they actually demonstrated; he shamelessly employed red herrings and non-sequiters and pushed people's hot buttons to the point of fear-mongering, including a lengthy discussion on the motivations of Google's founders that bordered on conspiracy theory. I dismissed the article as overblown hype, feeling like that Carr was either grasping for a scapegoat in a world that's changing too fast, or was manipulating public sentiment to boost his own career. I was surprised to realize how much attention his article was getting. I was even more surprised at quality of that attention – the uncritical praise and affirmation that the article received.

Early Research on the Internet and Its Effects

Carr was certainly not the first to express concerns about the effect of the internet. Surveys were conducted at least as early as 1994 to measure the effect of the internet on American life (Times Mirror Center for The People & The Press, 1994). By the late 1990s, the Pew Research

Center had begun to regularly review and research trends in internet use (Rainie, Lenhart, Fox, Spooner, & Horrigan, 2000). In 2001, Mark Prensky coined the term "digital natives" to describe those who have grown up with the internet at their fingertips and how they differ from "digital immigrants," i.e., those who were introduced to the internet in adulthood. By the time Carr started talking about the possibility of the internet causing neurological changes, studies to monitor social and psychological changes associated with the internet were already well underway, such as studies of cyber bullying (see, for example, Finkelhor, Mitchell & Wolak, 2000), "echo chambers" (Reese, Rutigliano, Hyun & Jeong, 2007), and internet addiction (Young, 1996).

By 2005, librarians were already trying to name and quantify another phenomena they were observing as a result of widespread internet use, particularly school and academic librarians—the people tasked with teaching students to access and use library information resources. According to one report (Lippincott, 2005), new students seemed more and more reluctant to use library resources, preferring Google for everything, but the students surveyed in this report also did not seem to be able to evaluate information resources for quality or even relevance. Even more troubling, these young people seemed completely unaware, or unwilling to believe, that there is a difference between scholarly information and other information found on internet web sites. And finally, the report noted that "they no longer read, period" (Lippincott, 2005, p. 13.6).

As librarians were just beginning to discuss "information literacy" and the need for more explicit instruction to incoming college students, Carr's article was published, asserting that focused reading was becoming a near impossibility. I remember discussing Carr's article with my fellow graduate students. Most, it seemed to me at the time, seemed too quick to agree with his conclusions, citing the fact that they hadn't read a novel in quite a while as proof that the internet was ruining their ability to read and think deeply. Judging from my own experience, I was not convinced: “The internet doesn’t distract people,” I debated facetiously; “people distract people.” While I admitted that I was more distracted and distractible than before, it was purely a matter of my lifestyle and priorities. I was more easily pulled away from my studies by the lure of a good video than by the internet, and during semester breaks, I still devoured a novel or two. And anyway, I had already noticed a change in my own reading habits before the internet had become a part of my everyday life. Convincing others, however, would be more difficult.

Even now, I’m baffled by the speed and certainty with which people blame the internet, and the lack of evidence other than their own subjective feeling that it must be true. Like Billy Crystal in his best New York accent, I’m thinking “Can’t we discuss this?” The collective lack of critical analysis, at least in popular opinion, makes me suspicious that this is a kind of denial that is masking a collective desire to avoid facing the real cause. On the other hand, I had a disconcerting suspicion that the general lack of critical analysis on this issue might also be, paradoxically, an example of exactly what Carr was talking about.

Why have so many people been so easily convinced that human cognitive functioning has been damaged at a neurological level, as Carr and others assert? Why are they so sure that this condition is the result of using the internet? And even if neurological changes are, in fact, occurring, what are the details? Does distraction necessarily preclude deep thinking? Are our brains really more predisposed to distraction now, as compared to earlier generations in modern history, or is there just more (or more distracting) stimulation in our environments to draw our attention away from less stimulating activities like reading or thinking deeply? If our brains really are structurally different now, how can we be sure of the cause? Rather than zero in on only one possible cause (i.e., the internet), why not examine all (or at least several) possible explanations? Isn’t it possible that an inability to concentrate could be the result of other changes in our society, of which the internet and other phenomena are just contributing factors or symptoms of a wider trend?

How to Approach This Problem

Most of what I've been reading starts from the belief (whether true or not) that (a) we *are* experiencing neurological changes in the way we read and process information, and (b) that these changes are caused by our use of the internet. With those two beliefs taken for granted, there is much debate about whether these changes are good or bad, whether they will increase our knowledge or cause a decline (see, for example, Robbins, 2013, and Zimmer, 2009). People wonder whether we have reason to be worried or excited. My concern, however, is that we have been too quick to accept the first two assertions.

The purpose of this paper is to start at the beginning and explore the issue more fully. If many people are, in fact, becoming more easily distracted and less able to think deeply, then it is indeed a worrisome trend that ought to be examined. It would be equally disturbing if the internet is found to interfere with human capacity for contemplation. However, it is important – perhaps even vitally important to our development as individuals and as a society – to determine exactly what is happening or not happening. Only after we can pinpoint the problem and determine a specific avenue for inquiry, or multiple avenues, validated by empirical data, is it useful to consider the problem's cause(s) and effects. If we allow ourselves to be misled by a convenient but incorrect scapegoat, we may not see the real cause for concern until it has become more firmly entrenched

Conducting Research on the Neurology of Cognitive Processes

Eminent physicist Werner Heisenberg (1959) famously wrote, "What [scientists] observe is not nature itself but nature exposed to our method of questioning" (p. 57). More recently, Stan Klein, psychology professor and cognitive neuroscience researcher at UC Santa Barbara, expounds on Heisenberg's point as it relates to current methods in cognitive neuroscience research, explaining that “The scientific approach to understanding consists in asking questions [about] some provision or predicted consequence of a conceptually well-specified theory…. This questioning most often is accomplished by means of experimentation…; however, the scientific enterprise is *more* than the construction and interpretation of the observational offerings of well-designed experiments…. Asking the ‘right’ question is critical to obtaining a solution to problems posed” (Klein, S.B., 2013, p. 118-119).

Asking the Right Question

Carr's question "What is the internet doing to our brains?" seems to have touched a collective nerve, so it is a good starting point. However, in order to explore that question, it would be useful to clarify it by breaking it down into its component parts:

1. In order to better understand what exactly is happening, we have to be able to isolate, test, observe, measure and quantify the problem. What are the tools and methods available to us now? Do they adequately consider the complexity of the problem and difficulty of isolating the salient factors (Carter, Aldridge, Page, & Parker, 2009), the limitations of current tools and technology for observing neurological phenomena (Klein, C., 2010; Klein, S. B., 2013; Satel & Lilienfeld, 2013; Sawyer, 2011), the ethics of conducting experiments on human subjects, and the difficulty of testing our own thought processes without falling prey to the same logical blind spots and distorted interpretations we are trying to measure (Burton, 2013; Klein, S. B., Satel & Lilienfeld)?

2. If neurological changes are observed, how can we be sure that the internet is the cause of the observed changes? Other explanations are possible, such as the proliferation of television, or increasingly aggressive marketing and advertising, or increased consumption of medicines or pesticides or preservatives or GMO foods or fluoridated water, or stress associated with normal life in a developed country, some of which may have begun a decade (or a century) before the internet was introduced. How can these and other possible causes be isolated each other? Which, if any, have been scientifically studied, and what do those studies reveal about changes in human cognitive neurology? If the timing is determined to have been concurrent with the introduction of the internet, what *else* was happening at that time that could account for the observed neurological changes?

3. If reliable data is available, what patterns can be detected?
   - Is everyone experiencing the same kinds of changes? If not, what are the variations, and what accounts for them? Or is the change occurring at a societal level?
   - If only some individuals can be observed as exhibiting neurological changes, then which parts of the population are experiencing it and which are not? Do the observed changes vary among different individuals, with some individuals affected in one way, and other individuals affected in other ways?
4. In practical terms, how *useful* is the data? How conclusive is the data, what are its limitations, and how wide is the margin of error? How might we use data that's currently available to guide the direction of future research and apply our findings appropriately and effectively? And can it help us determine the best course of action for ensuring a better future?

Gathering Data

In a sense, scientific experiments must be conducted from an already-biased position – i.e., the scientist states a hypothesis and then looks for evidence that either supports the hypothesis or clearly refutes it. In the physical sciences, this can be tricky enough, even with evidence that is clear and measurable (e.g., a solar eclipse that either occurs at the predicted hour, or doesn't). In the social sciences, however, it is impossible to observe the salient features directly (more on this point later). Cognition is not completely devoid of physical features, but these have been difficult to recognize, much less observe during controlled experiments, because the physical features associated with cognition (as we currently understand them) are located inside the skull and occur at a microscopic level. Throughout most of human history, the importance of the brain for cognition seemed to have been completely overlooked:

> "Until about a hundred years ago, the only evidence that brain and mind were connected was obtained from 'natural experiments'—accidents in which head injuries created aberrations in their victims' behavior. Dedicated physicians mapped out areas of the cerebral landscape by observing the subjects of such experiments while they were alive—then matching their deficits to the damaged areas of their brains. It was slow work because the scientists had to wait for their subjects to die before they could look at the physiological evidence." (Carter et al., 2009, p.6).

Even with current understanding of neurology and the anatomy of the human brain, the latest imaging technology "reveals the brain to be an astonishingly complex, sensitive system in which each part affects almost every other" (Carter et al., 2009, p. 7) — thus the difficulty of isolating individual neurological and cognitive processes for observation.

Current Tools and Methods

Having the right tools for studying such "an astonishingly complex and sensitive system" (Carter et al., 2009, p. 7) is essential, and unfortunately, the tools currently available to us can only provide crude representations and indirect observations.

The first observations of the brain were conducted by a Canadian brain surgeon named Wilder Penfield: "While the brain was exposed, and the patient conscious, Penfield probed the cortex with an electrode and noted the responses of the patient as he touched each part.... [and] much of the basic map [of the brain] was established by Penfield" in the 1950s (Carter et al., 2009, p. 10). However, this is a highly invasive method for conducting controlled experiments on human subjects. Fortunately there are other methods for studying the structure of the brain that do not require cutting into the body, and that offer a view of the deeper structure of the brain. CT (computer tomography) and MRI (magnetic resonance imagery) create x-ray-like images, slice by slice, of any part of the body. Because they are good at distinguishing soft tissue from bone without having to cut into the body, CT scans are often used to identify tumors (Carter et al., 2009). "A refinement of MRI called diffusion tensor imaging picks up the passage of water along nerve fibers" (Carter et al., 2009, p. 13). CT and MRI reveal only the static structure of the brain.

Functional brain imaging allows us to observe and measure activity within the brain as it is happening, which is necessary in order to test for brain activity during controlled experiments. Types of functional brain imaging include EEG (electroencephalography), which measures the tiny electrical charges that are created when nerve cells fire, and MEG (magnetic-encephalography), which measures the magnetic fields created by those electrical charges. Other types of functional brain imaging measure the metabolic side effects of brain activity, such as alterations in glucose absorption (measured by PET, i.e., positron emission tomography), and blood flow in the brain (measured by fMRI, or functional magnetic resonance imaging). There is much more that could be said about these technologies that is beyond the scope of this paper.

Limitations of Current Tools and Methods

Having extremely reliable and sophisticated tools is important because empirical science depends on observable, measurable, quantifiable raw data that can be manipulated and interpreted with some degree of objectivity. In the case of cognitive neuroscience, having reliable and sophisticated tools is especially important because of the difficulty of observing neurological phenomena at all, much less with any degree of accuracy. In general, and despite high standards, the research process is fraught with inaccuracy and error, whether in the data itself, or in the subjective judgments of the researchers who observe, measure and interpret the data. Some limitations are known and accounted for; too often, acknowledgment of limitations is glossed over, and research is presented as conclusive and unambiguous fact. The history of science and medicine is replete with instances of misinterpreted data leading to the wrong conclusions that were first hailed and then reversed. Mistakes, false turns and dead ends are, in fact, a necessary part of the scientific process, and even such misunderstandings are valuable in terms of what they can reveal. Reversals of scientific "fact" actually offer reassuring proof of the rigor of scientific method. Nevertheless, it can be a painful process, which includes acknowledging limitations and integrating that acknowledgment into any discussion of what is thought to be known and understood. The following subsections discuss some of the limitations of studying cognitive neuroscience, in general, and research on how the internet might be affecting human cognition in particular.

Ethics of Human Subject Research. The past hundred years of experimentation in psychology and cognitive neuroscience have demonstrated that strict laws and guidelines from within the worldwide medical and scientific community are necessary and desirable in order to protect human subjects from both abuse and unintended consequences. These laws and guidelines are continually updated, and much of the early research in psychology and cognitive neuroscience would not have been approved by today's ethics review boards, although many are considered seminal studies that greatly contributed to our understanding of the cognitive sciences. A general understanding of ethics can probably be assumed for those reading this paper, and a full discussion of the topic is beyond the scope of my research. Suffice it to say that, regardless of how much might be learned from experiments that involve, for example, removing parts of an individual's brain and then observing the effects, or raising a child in an environment with no books but only the internet to read from, simply would not – and should not – be done, no matter how much useful data would be collected for research purposes. It is mentioned here for the sake of completion, only, as it is the first obvious limitation in my list.

Difficulty of Observing Mental Processes. In addition to ethical considerations, there is also significant difficulty in devising experiments that can, somehow, reveal internal thoughts and feelings in the form of data that can be used in scientific analysis. As Stan Klein writes, “the social sciences suffer from a paucity of abstract formalizations capable of supporting the type of precise theory-based predictions and specifications found in most of the physical sciences...; [therefore] social scientists are at a clear disadvantage when it comes to determining whether our experimental outcomes are commensurate with, or antithetical to, whatever theoretical topic is under examination” (Klein, S.B., 2013, pp. 119-120).

Non-physical phenomena cannot be observed directly. To observe non-physical phenomena such as thoughts and emotions, cognitive neuroscientists look for some kind of physical representation that can be said to demonstrate evidence of a non-physical emotional or cognitive process. For example, an fMRI machine records blood flow in the subject’s brain, and when a subject is instructed to perform mental mathematical calculations, scientists can observe which parts of the brain experience changes in blood flow. That representation is not, therefore, a direct observation of cognition but only an indirect observation of the physical phenomena that occur at the same time as cognition. The data observed by cognitive neuroscience is naturally inexact because any representation is inexact; like a photocopy of a photocopy, each representation is less exact than what it represents, the data deteriorates with each step further removed from the original.

Limitations of Tools & Technology. The technology for studying brain functions has known limitations (Klein, C., 2010). Furthermore, current tools and technology for studying cognitive neuroscience are quite new and are still in the relatively early stages of development. For example, fMRI scanners were only invented in the 1990s. Although these technologies are able to provide far more data associated with cognition than anything ever before, their capabilities are universally acknowledged to be limited. For example, “Each [type of technology] has its own strengths and limitations" (Sawyer, 2011, p. 138); "MRI is good at detail, for example, but is too slow to chart fast-moving events. EEG and MEG are fast but are not as good at pinpointing location" (Carter et al., 2009, p. 13). Additionally, data on areas of the brain associated with which different cognitive functions is far from definitive, and "areas [of brain activity] used in a task vary from person to person, so studies often combine data from volunteers to give an average" (Carter et al., 2009, p. 13). Despite these known and quantifiable limitations, observations of brain activity, however flawed, are frequently reported in unambiguous terms – not only in popular media, but also in textbooks, scholarly journals and other reputable scientific information resources. (See below for some examples.)

Aside from debates about the accuracy and overall value that functional imaging tools can provide, some skeptics also question the underlying assumptions on which these techniques rely, e.g., the assumption that the location where brain activity is observed is actually where the cognitive function is taking place. For example, cognitive neuroscientist Stan Klein (2013) writes that many of the current technologies used by neuroscientists to study cognitive processes "assume an equivalence between construct and observation: i.e., that the neural structures activated during radiological analysis are in some (unspecified) way coextensive with the construct under consideration" (p. 126). *The Human Brain Book* (Carter et al., 2009), for example, has literally hundreds of diagrams of different parts of the brain and the cognitive function that are thought to be associated with them, with accompanying descriptions written in language that implies an unwarranted degree of certainty, such as, for example, "Several brain areas deal with numbers: estimates come from the intraparietal sulcus; the superior temporal sulcus deals with numerical values in abstract form; and the mid-frontal area notes when numbers seem wrong" (p.167). Stan Klein (2013) continues that "it is one thing to argue that neural activity is correlated with mental activity, and quite another to presume the two are coextensive" (p. 126), and considering the limitations outlined in this and earlier sections, it certainly does seem presumptuous to write about brain function in such unequivocal terms.

An additional limitation that I have not seen discussed anywhere, is that these technologies only study the outer surface of the brain – the neocortex, i.e. the outermost layer of the brain that contains neurons and blood vessels that supply blood to them (Sawyer, 2011). "Cognitive neuroscientists focus on the neocortex… because it is responsible for all higher-level mental functions" (Sawyer, 2011, p. 138). This, however, is exactly the type of statement that sounds far too conclusive for what we currently know. It would be more accurate to say something like, "Cognitive neuroscientists focus on the neocortex because more neurons have been observed in the neocortex than anywhere else, and neurons are thought to be the main anatomical features involved in cognitive processes." By now, both the scientific community and the general public ought to be aware that what we can observe is often only a fraction of what is actually there. (On the other hand, rather than a limitation of current technology, this may be an example of scientists framing of the question in a way that inappropriately limits our understanding of the topic, and unwittingly ignores whole avenues for of research.)

Interpreting the Results

As mentioned in previous sections, it is not scientifically possible to observe cognition. That statement sounds extreme to some people, but it is accurate: current scientific method does not have any reliable tool or method for observing mental phenomena directly. Thoughts and emotions, thinking and feeling, cognition and understanding – these currently have no anatomical correlates and cannot, themselves, be observed. Instead, what is studied are the indirect indications of mental activity, such as changes in blood flow or electro-magnetic fields. After measuring the indirect phenomenon that is thought to correlate to the mental phenomenon, a machine, such as an fMRI scanner, renders another representation of the observed phenomenon. The image of the scan is then studied and interpreted by scientists, who naturally form their own mental representation of what they are seeing (Reisberg, 2013) – i.e., they form their own mental representation of the machine's physical representation of some kind of observable, physical activity that occur in the research participant's brain at the same time as he or she performs a specified mental task. As mentioned previously, the data deteriorates with each step that it is removed from the original, which means there is significant cause for concern about the reliability of the current research in cognitive neuroscience. The cause for concern is compounded when we consider the biases and cognitive limitations of the researchers themselves because, just as it is impossible to observe cognition directly, it is also often impossible to draw definitive conclusions from the evidence that is actually observed and measured from research in the cognitive sciences without also employing a significant amount of interpretation.

There are some (such as Burton, 2013; Satel & Lilienfeld, 2013) who even argue that the human brain is not cognitively able to examine or interpret its own processes and functions without significant distortion, circular reasoning and logical oversights. Satel and Lilienfeld (2013) state it pithily when they write "the illuminated brain cannot be trusted to offer an unfiltered view of the mind" (p. 150). Biases are natural, easily overlooked, and very understandable, but if left unchecked, they may have disastrous consequences for science. For example, phrenology – which is based on physical, observable phenomena – was once thought to be a science. The lobotomy, for which its inventor was awarded the Nobel Prize, was once considered a relatively mild procedure (Goodman, 2008) but is now "considered a barbaric treatment for mental illness" (Weiner, 2005). Many errors in scientific understanding result from the belief that "what [we] see is all there is" (Kahneman, 2011, p. 85). Germ theory is one obvious example, and the fact that it took generations for the medical community to agree that hand washing is good medical practice. In a similar example, medical and scientific understanding of nutrition was greatly limited prior to the discovery of vitamins, and my grandmother recalled a time in the 1920s when impoverished Italian immigrants in New York City were advised by public health officials not to waste their money on vegetables because vegetables, they said, have only limited value as carbohydrates and otherwise have no nutritional value.

Despite all of the limitations of current tools, technologies and methods in cognitive neuroscience that have been discussed in the previous several pages, it is not my intention to imply that current research is worthless or that it should be disregarded wholesale. All reliable data is potentially useful. However, reliable data does not guarantee conclusions that are reliable or conclusive. Rather than consider current research as anything definitive, it may be more useful to think of it like a jigsaw puzzle, and to consider that we've only just started to collect the pieces one place, and we don't know what size or shape the finished product will be, or even what the big picture is that we're trying to construct. In terms of what the internet is doing to our brains, I suggest that it would be useful to refrain from drawing hasty conclusions about the internet causing neurological damage based on a few studies whose only evidence is what's indicated on images rendered from fMRI brain scans.

We are now ready to discuss the research that has been done to help us understand how the internet is affecting human cognition.

Data Available to Us Now

There is a vast and overwhelming amount of research on the effects of frequent internet use on human cognitive function, including the effects on individual psychology and sociology, its implications for use in fields as diverse as criminology, education, architecture and computer science. This paper focuses specifically on research in cognitive neuroscience. Even then, there are a variety of angles from which to study the general question of what the internet is doing to our brains. The following are some of the areas studied, with much overlap; the list is far from comprehensive:

- multi-tasking, also called "continuous partial attention"
- attention and distractibility
- memory and recall
- internet addiction (the neurology of)
- information overload
- internet and the sense of self
- internet and expanded mind theory
- online gaming (e.g. visual and spatial processing)

Considering the amount of research being conducted in each of these areas, even a brief overview would be far beyond the scope of this paper. However, a closer examination of the broader question can provide a framework from which to better understand research that we might read about in popular media.

It turns out that, according to current understanding of cognitive neuroscience, Carr's assertion (2008, 2010) that the internet is "rewiring our brains" is true but is much less sinister than it sounds because, apparently, the brain's the neural circuitry changes with everything we do. This, in turn, is thought to be the essence of learning.

In fact, the ability to form new neural connections is the basis for the theory of human brain plasticity, or neuroplasticity, which appears to be undisputed in the scientific community. In a nutshell, the theory says that every time you do something new, your brain forms new "neural pathways," and the more you repeat that activity, the more entrenched the route becomes (Leysen, S.L., 2013). The general idea is that electro-neurons are thought to travel along these neural pathways like couriers running through a network of trenches from "command central," i.e. the brain, to the troops at the front line, carrying messages to tell the different parts of our body what to do, so that every big, small, microscopic, conscious, unconscious, muscular or hormonal activity in the body is directed by these electro-neural instructions from the brain.

With each repetition of an activity, the neural pathway is thought to morph and become more direct, cutting corners and straightening the curves to form a direct route from command central to the theatre of action (Leysen, 2013). Metaphorically, it's like the difference between the way you do anything the first time compared to the way you do it after countless repetitions. At first you follow the directions carefully, step-by-step; with repetition, you can do it literally without even thinking. Imagine a time when you moved to a new home: at first you mentally walk yourself through each part of the trip, noticing every landmark and thinking through each turn you make – turn left onto Main Street, look for the post office, make the next right, and so on. After commuting to and from your home a few times, you might figure out a shortcut or alter your route to avoid a congested intersection. After a while, you probably get to the point where you're standing at your front door and can't remember how you got there. New neural pathways are thought to be formed in the same way, continually created, revised and refined for efficiency (Leysen, 2013).

In that sense, then, the internet can be said to cause changes in our brains and our neural pathways because interacting with the internet involves a different set of neural pathways than other activities, such as reading books, playing sports and other games, and interacting with people in the real world, and the human brain adapts by forming new neural pathways to perform those tasks most efficiently. This, in itself, would generally be considered a good thing if not for two other concepts in the theory of neuroplasticity.

The first is that, like a real pathway, a well-worn neural pathway is thought to become so well established that it is difficult for neurons to take a different route, as if the neurons become stuck in a neurological rut. This would explain why habits – even bad habits – are so hard to break, and why it is sometimes easier to learn something from scratch than to make even slight changes in the way you do something that's become second nature.

If neural connections are strengthened with repeated use, then frequent users of the internet will develop stronger neural pathways for online activities, and if they spend more time online than on other activities, then the neural pathways associated with performing online activities will eventually become stronger than the neural pathways associated with other activities. This would then enable a person to perform those online activities more efficiently than activities performed in the real world, which encourages them to perform those activities more often, and it becomes a self-reinforcing cycle. Eventually, a person inclined to interact online becomes less and less able or inclined to do other activities until they are, in a sense, stuck in a neurological rut, from which it is difficult to break out of. For some, this is disturbing in and of itself. For others the concern is in the broader implications of using the internet to the exclusion of other activities (more on that below).

There is a second and admittedly more disturbing disadvantage of neural plasticity and how it relates to frequent internet use. According to the theory of neuroplasticity, neural pathways are continually at risk of being appropriated by other, more active neural pathways (Leysen, 2013). This, it appears, is the biggest concern about "what the internet is doing to our brains," particularly for children who have grown up with the internet and cell phones at their fingertips (Prensky, 2005; Wolf, 2007; Terkel, 2011). The fear is that, by interacting with the internet more often than doing other activities, such as reading a book, the neural pathways for the less-frequent activities will be appropriated and repurposed for more-frequent activities. In other words, if you use the internet too often without also continuing to read books, then you will eventually lose the ability to read books altogether, and it will be very hard to regain the ease of reading books that you once had. This is especially concerning for children, whose neural pathways associated with internet use may already be much stronger than their neural pathways for deep reading (Prensky, 2005; Wolf, 2007, and many others).

Conclusion

Many people seem to feel that, just as developing new neural pathways for new activities is a good thing – the essence of learning – we need not be concerned if the internet is causing changes in our brains' neural circuitry; see, for example, Paul Smart's well-balanced discussion of this topic in his paper, "Cognition and the Web" (2009). Many other people, however, are concerned that the new neural circuitry is a poor substitute for the old, and that higher order thinking such as critical analysis, creativity, problem solving, and deep, focused concentration are being replaced by quick and superficial skimming of details, and shallow, distracted thinking (Wolf, 2007; Ophir, Nass, Wagner, & Posner, 2009; Smart, 2009; Carr, 2008 and 2010; Ritchel, 2010; Smith, 2010; Rose, 2011; Robbins, 2012; Parry, 2013; Jabr, 2014, and many more). The theory of neuroplasticity says that that the new neural pathways for performing online activities are crowding out or taking over the less-frequently used neural pathways. It remains unclear whether or not the new neural pathways really do cause a degradation in the quality of human thought, as is feared, and whether or not the internet use causes a fundamental shift in the neurological factors involved in cognition. There have been literally hundreds, if not thousands of studies on different aspects of this question; none yet is conclusive.

References

Burton, R. A. (2013). *A skeptic's guide to the mind: What neuroscience can and cannot tell us about ourselves.* New York, NY: St. Martin's Press.

Carr, N. (2008, July 1). Is Google making us stupid? What the internet is doing to our brains. *The Atlantic*. Retrieved from http://www.theatlantic.com/magazine/archive/2008/07/is-google-making-us-stupid/306868/

Carr, N. (2010). *The shallows: What the internet is doing to our brains.* New York, NY: W. W. Norton & Company.

Carter, R., Aldridge, S., Page, M. & Parker, S. (2009). *The human brain book.* London, UK: DK Books.

Farah, M. J. (2014). Brain images, babies, and bathwater: critiquing critiques of functional neuroimaging. *Hastings Center Report, 44.* S19-S30. doi:10.1002/hast.295

Finkelhor, Mitchell & Wolak, (2000, June). *Online victimization: A report on the nation's youth.* Crimes against Children Research Center, Durham, NH. Retrieved from http://files.eric.ed.gov/fulltext/ED442039.pdf

Goodman, B. (Writer, Producer & Director) and Maggio, J. (Producer & Director). (2008). *The lobotomist* [*American Experience*]. Public Broadcasting Service. Available from http://www.shoppbs.org/ product/index.jsp?productId=2966810

Heisenberg, W. (1959). *Physics and philosophy: The revolution in modern science.* London, UK: Ruskin House. Retrieved from https://archive.org/stream/ost-physics-heisenberg-physicsphilosophy/Heisenberg-PhysicsPhilosophy#page/n27/mode/2up

Jabr, F. (2013). The reading brain in the digital age: The science of paper versus screens. *Scientific American.* Retrieved from http://www.scientificamerican.com/article/reading-paper-screens/

Kahneman, D. (2011). *Thinking fast and slow.* New York, NY: Farrar, Straus and Giroux.

Klein, C. (2010, June). Images are not the evidence in neuroimaging. *British Journal for the Philosophy of Science, 61*(2), 265-278. Retrieved from http://colinklein.org/papers/ImagingWebVers.pdf

Klein, S. B. (2013). Images and constructs: Can the neurological correlates of self be revealed through radiological analysis? *International Journal of Psychological Research 6*(Special Issue), 117-132. Retrieved from http://dialnet.unirioja.es/servlet/articulo?codigo=4548401

Leysen, S. L. (2011, May 9). Brain plasticity and the impact of the electronic environment in law and learning. *Legal Reference Services Quarterly, 30*(4), 255-288.

Lippincott, J. K. (2005). Net generation students and libraries. In Oblinger, D. G., & Oblinger, J. L., (Eds.), *Educating the Net Generation* (Ch. 13). Retrieved from http://www.educause.edu/research-and-publications/books/educating-net-generation

Oberdan, T. (2009). Google and Gödel. *Bulletin of Science Technology & Society, 29*(6), 464-469.

Ophir, E., Nass, C., Wagner, A. D. & Posner, M. I. (2009, September 15). Cognitive control in media multitaskers. *Proceedings of the National Academy of Sciences of the United States of America, 106*(37), pp. 15583-15587. Retrieved from http://www.jstor.org/stable/40484765

Parry, M. (2013, March 24). You're distracted: This professor can help. *The Chronicle of Higher Education.* Retrieved from https://chronicle.com/article/Youre-Distracted-This/138079/

Prensky, M. (2001). Digital natives, digital immigrants. Retrieved from http://www.marcprensky.com/writing/Prensky%20-%20Digital%20Natives,%20Digital%20Immigrants%20-%20Part1.pdf

Prensky, M. (2001). Digital natives, digital immigrants – part II: Do they really think differently? Retrieved from http://www.marcprensky.com/writing/Prensky%20-%20Digital%20Natives,%20Digital%20Immigrants%20-%20Part2.pdf

Rainie, L., Lenhart, A., Fox, S., Spooner, T., & Horrigan, J. (2000, May 10). Tracking online life. *Pew Research Internet Project.* Retrieved from http://www.pewinternet.org/2000/05/10/tracking-online-life/

Reese, Rutigliano, Hyun & Jeong, (2007). Mapping the blogosphere: Professional and citizen-based media in the global news arena. *Journalism: Theory, Practice and Criticism, 8*(3), 235–262. Retrieved from http://shs.ntu.edu.tw/course/uploads/week_20121221054258_2314.pdf

Reisberg, D. (2013). *Cognition: Exploring the science of the mind* (5th ed.). New York, NY: W. W. Norton & Company.

Ritchel, M. (2010, June 6). Attached to technology and paying a price." *New York Times.* Retrieved from http://www.nytimes.com/2010/06/07/technology/07brain.html?pagewanted%253Dall&_r=0

Robbins, J. (2012). Technology: The cause of negative neurological changes or an extension of oneself? *Berkeley Scientific Journal, 15*(1).

Rose, E. (2011). Continuous partial attention: Teaching and learning in the age of interruption. Retreived from http://scholar.google.com/scholar?hl=en&q=Ellen+Rose+Continuous+Partial+Attention%3A+teaching+and+learning+in+the+age+of+interruption&btnG=&as_sdt=1%2C22&as_sdtp=

Satel, S. and Lilienfeld, S. O. (2013). *Brainwashed: The seductive appeal of mindless neuroscience.* New York, NY: Basic Books.

Sawyer, K. (2011). The cognitive neuroscience of creativity: A critical review. *Creativity Research Journal, 23*(2), 137-154.

Smart, P. (2009, 22 September). Cognition and the web. *1st ITA Workshop on Network-Enabled Cognition: The Contribution of Social and Technological Networks to Human Cognition, Maryland, USA.* Retreived from http://eprints.soton.ac.uk/271824/

Smith, N. (2010). Stupider and worse? *The University Dialogue.* Paper 62. Retrieved from http://scholars.unh.edu/discovery_ud/62

Times Mirror Center for The People & The Press. (1994, May 24). *Technology in the American household.* Retrieved from http://www.people-press.org/files/legacy-pdf/582.pdf

Turkle, S. (2011). *Alone together: Why we expect more from technology and less from each other.* New York, NY: Basic Books.

Weiner, E. (2005, August 10). *Nobel panel urged to rescind prize for lobotomies.* [Podcast]. Retrieved from http://www.npr.org/templates/story/story.php?storyId=4794007&ps=rs

Young, K. S. (1996). Internet addiction: The emergence of a new clinical disorder. *CyberPsychology & Behavior, 1*(3): 237-244. Retrieved from http://www.chabad4israel.org/tznius4israel/newdisorder.pdf

Zimmer, C. (2009, January 15). How Google is making us smarter: Humans are "natural-born cyborgs," and the internet is our giant "extended mind." *Discover Magazine.* Retrieved from http://discovermagazine.com/2009/feb/15-how-google-is-making-us-smarter#.Uy0Xl1ewUVS