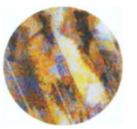
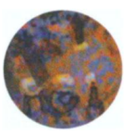


The Juggler's Brain



The hours that we spend exploring the Internet are changing our brains — and **not** necessarily for the better.

By Nicholas Carr

During the course of a day, most of us with access to the web spend at least a couple of hours online — sometimes much more — and during that time, we tend to repeat the same or similar actions over and over again, usually at a high rate of speed and often in response to cues delivered through a screen or a speaker. Some of the actions are physical ones. We tap the keys on our PC keyboard. We drag a mouse and click its left and right buttons and spin its scroll wheel. We draw the tips of our fingers across a trackpad. We use our thumbs to punch out text on the real or simulated keypads of our BlackBerrys or mobile phones. We rotate our iPhones, iPods, and iPads to shift between "landscape" and "portrait" modes while manipulating the icons on their touch-sensitive screens.

As we go through these motions, the Net delivers a steady stream of inputs to our visual, somatosensory, and auditory cortices. There are the sensations that come through our hands and fingers as we click and scroll, type and touch. There are the many audio signals delivered through our ears, such as the chime that announces the arrival of a new e-mail or instant message and the various ringtones that our mobile phones use to alert us to different events. And, of course, there are the myriad visual cues that flash across our retinas as we navigate the online world: not just the ever-changing arrays of text and pictures and videos but also the hyperlinks distinguished by underlining or colored text, the cursors that change shape depending on their function, the new e-mail subject lines highlighted in bold type, the virtual buttons that call out to be clicked, the icons and other screen elements that beg to be dragged and dropped, the forms that require

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NICHOLAS CARR, a former executive editor of the *Harvard Business Review*, writes on the social, economic, and business implications of technology.

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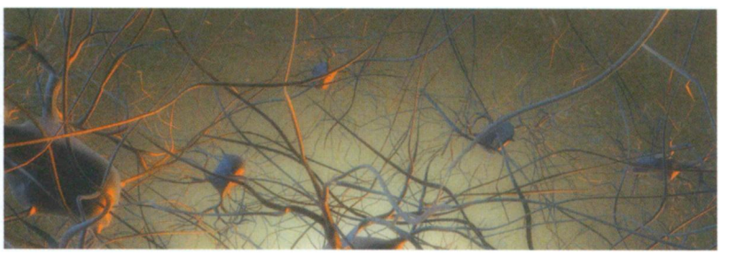
filling out, the pop-up ads and windows that need to be read or dismissed. The Net engages all of our senses — except, so far, those of smell and taste — and it engages them simultaneously.

The Net also provides a high-speed system for delivering responses and rewards — "positive reinforcements," in psychological terms — that encourage the repetition of both physical and mental actions. When we click a link, we get something new to look at and evaluate. When we Google a keyword, we receive, in the blink of an eye, a list of interesting information to appraise. When we send a text or an instant message or an e-mail, we often get a reply in a matter of seconds or minutes. When we use Facebook, we attract new friends or form closer bonds with old ones. When we send a tweet through Twitter, we gain new followers. When we write a blog post, we get comments from readers or links from other bloggers. The Net's interactivity gives us powerful new tools for finding information, expressing ourselves, and conversing with others. It also turns us into lab rats constantly pressing levers to get tiny pellets of social or intellectual nourishment.



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Just as neurons that fire together wire together, neurons that don't fire together don't wire together. We gain new skills and perspectives, but lose old ones.

The Net commands our attention with far greater insistency than our television or radio or morning newspaper ever did. Watch a kid texting his friends or a college student looking over the roll of new messages and requests on her Facebook page or a businessman scrolling through his e-mails on his BlackBerry — or consider yourself as you enter keywords into Google's search box and begin following a trail of links. What you see is a mind consumed with a medium. When we're online, we're often oblivious to everything else going on around us. The real world recedes as we process the flood of symbols and stimuli coming through our devices.

SCATTERING OUR ATTENTION

Our use of the Internet involves many paradoxes, but the one that promises to have the greatest long-term influence over how we think is this one: The Net seizes our attention only to scatter it. We focus intensively on the medium itself, on the flickering screen, but we're distracted by the medium's rapid-fire delivery of competing messages and stimuli. Whenever and wherever we log on, the Net presents us with an incredibly seductive blur. Human beings "want more information, more impressions, and more complexity," writes Torkel Klingberg, the Swedish neuroscientist. We tend to "seek out situations that demand concurrent performance or situations in which [we] are overwhelmed with information" (2009: 166-167). If the slow progression of words across printed pages dampened our craving to be inundated by mental stimulation, the Net indulges it. It returns us to our native state of bottom-up distractedness, while presenting us with far more distractions than our ancestors ever had to contend with.

The constant distractedness that the Net encourages — the state of being, to borrow a phrase from T.S. Eliot's *Four Quartets*, "distracted from distraction by distraction" — is very different from the kind of temporary, purposeful diversion of our mind that refreshes our thinking when we're weighing a decision. The Net's cacophony of stimuli short-circuits both conscious and unconscious thought, preventing our minds from thinking either deeply or creatively. Our brains turn into simple signal-processing units, quickly shepherding information into consciousness and then back out again.

In a 2005 interview, the pioneering neuroscientist Michael Merzenich ruminated on the Internet's power to cause not just modest alterations but fundamental changes in our mental makeup. Noting that "our brain is modified on a substantial scale, physically and functionally, each time we learn a new skill or develop a new ability," he described the Net as the latest in a series of "modern cultural specializations" that "contemporary humans can spend millions of 'practice' events at [and that] the average human a thousand years ago had absolutely no exposure to." He concluded that "our brains are massively remodeled by this exposure" (Olsen 2005). He returned to this theme in a post on his blog in 2008, resorting to capital letters to emphasize his points. "When culture drives changes in the ways that we engage our brains, it creates DIFFERENT brains," he wrote, noting that our minds "strengthen specific heavily-exercised processes." While acknowledging that it's now hard to imagine living without the Internet and online tools like the Google search engine, he stressed that "THEIR HEAVY USE HAS NEUROLOGICAL CONSEQUENCES."

What we're *not* doing when we're online also has neurological consequences. Just as neurons that fire together wire together, neurons that don't fire to-

gether don't wire together. As the time we spend scanning Web pages crowds out the time we spend reading books, as the time we spend exchanging bite-sized text messages crowds out the time we spend composing sentences and paragraphs, as the time we spend hopping across links crowds out the time we devote to quiet reflection and contemplation, the circuits that support those old intellectual functions and pursuits weaken and begin to break apart. The brain recycles the disused neurons and synapses for other, more pressing work. We gain new skills and perspectives but lose old ones.

MEMORY LOAD

The depth of our intelligence hinges on our ability to transfer information from working memory to long-term memory and weave it into conceptual schemas. But the passage from working memory to long-term memory also forms the major bottleneck in our brain. Unlike long-term memory, which has a vast capacity, working memory is able to hold only a very small amount of information. In a renowned 1956 paper, "The Magical Number Seven, Plus or Minus Two," Princeton psychologist George Miller observed that working memory could typically hold just seven pieces, or "elements," of information. Even that is now considered an overstatement. According to educational psychologist John Sweller, current evidence suggests that "we can process no more than about two to four elements at any given time with the actual number probably being at the lower [rather] than the higher end of this scale." Those elements that we are able to hold in working memory will, moreover, quickly vanish "unless we are able to refresh them by rehearsal" (Sweller 1999: 4-5).

Imagine filling a bathtub with a thimble; that's the challenge involved in transferring information from working memory into long-term memory. By regulating the velocity and intensity of information flow, media exert a strong influence on this process. When we read a book, the information faucet provides a steady drip, which we can control by the pace of our reading. Through our single-minded concentration on the text, we can transfer all or most of the information, thimbleful by thimbleful, into long-term memory and forge the rich associations essential to the creation of schemas. With the Net, we face many information faucets, all going full blast. Our little thimble overflows as we rush from one faucet to the next. We're able to transfer only a small portion of the information to long-term memory, and what we do transfer is a jumble of drops from different faucets, not a continuous, coherent stream from one source.

The information flowing into our working memory at any given moment is called our "cognitive load." When the load exceeds our mind's ability to store and process the information — when the water overflows the thimble — we're unable to retain the information or to draw connections with the information already stored in our long-term memory. We can't translate the new information into schemas. Our ability to learn suffers, and our understanding remains shallow. Because our ability to maintain our attention also depends on our working memory — "we have to remember what it is we are to concentrate on," as Torkel Klingberg says — a high cognitive load amplifies the distractedness we experience. When our brain is overtaxed, we find "distractions more distracting" (Klingberg 2009: 39, 72-75). (Some studies link attention deficit disorder, or ADD, to the overloading of working memory.) Experiments indicate that as we reach the limits of our working memory, it becomes harder to distinguish relevant information from irrelevant information, signal from noise. We become mindless consumers of data.

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Difficulties in developing an understanding of a subject or a concept appear to be "heavily determined by working memory load," writes Sweller (1999: 22), and the more complex the material we're trying to learn, the greater the penalty exacted by an overloaded mind. There are many possible sources of cognitive overload, but two of the most important, according to Sweller, are "extraneous problem-solving" and "divided attention." Those also happen to be two of the central features of the Net as an informational medium. Using the Net may, as UCLA psychiatrist Gary Small suggests, exercise the brain the way solving crossword puzzles does. But such intensive exercise, when it becomes our primary mode of thought, can impede deep learning and thinking. Try reading a book while doing a crossword puzzle; that's the intellectual environment of the Internet.

DIGITAL VS. PAPER

Back in the 1980s, when schools began investing heavily in computers, there was much enthusiasm about the apparent advantages of digital documents over paper ones. Many educators were convinced that introducing hyperlinks into text displayed on computer screens would be a boon to learning. Hy-

pertext would, they argued, strengthen students' critical thinking by enabling them to switch easily between different viewpoints. Freed from the lockstep reading demanded by printed pages, readers would make all sorts of new intellectual connections among diverse texts. The academic enthusiasm for hypertext was further kindled by the belief, in line with the fashionable postmodern theories of the day, that hypertext would overthrow the patriarchal authority of the author and shift power to the reader. It would be a technology of liberation. Hypertext, wrote the literary theorists George Landow and Paul Delany (2001: 206-211), can "provide a revelation" by freeing readers from the "stubborn materiality" of printed text. By "moving away from the constrictions of page-bound technology," it "provides a better model for the mind's ability to re-order the elements of experience by changing the links of association or determination between them."

Try reading a book while doing a crossword puzzle; that's the intellectual environment of the Internet.

By the end of the decade, the enthusiasm had begun to subside. Research was painting a fuller, and very different, picture of the cognitive effects of hypertext. Evaluating links and navigating a path through them, it turned out, involves mentally demanding problem-solving tasks that are extraneous to the act of reading itself. Deciphering hypertext substantially increases readers' cognitive load and hence weakens their ability to comprehend and retain what they're reading. A 1989 study showed that readers of hypertext often ended up clicking distractedly "through pages instead of reading them carefully." A 1990 experiment revealed that hypertext readers often "could not remember what they had and had not read." In another study that same year, researchers had two groups of people answer a series of questions by searching through a set of documents. One group searched through electronic hypertext documents, while the other searched through traditional paper documents. The group that used the paper documents outperformed the hypertext group in completing the assignment. In reviewing the results of these and other experiments, the editors of a 1996 book on hypertext and cognition wrote that, since hypertext "imposes a higher cognitive load on the reader," it's no surprise "that empirical comparisons between paper presentation (a familiar situation) and hypertext (a new, cognitively demanding situation) do not always favor hypertext." But they predicted that, as readers gained greater "hypertext literacy," the cognition problems would likely diminish (Rouet and Levonen 1996: 16-20).

That hasn't happened. Even though the World Wide Web has made hypertext commonplace, indeed ubiquitous, research continues to show that people who read linear text comprehend more, remember more, and learn more than those who read text peppered with links.

"You expect me to check my text messages, twitter all my friends, load my iPod, watch American Idol *and still do my homework?"*

ENHANCING SOME SKILLS

There are compensations. Research shows that certain cognitive skills are strengthened, sometimes substantially, by our use of computers and the Net. These tend to involve lower-level, or more primitive, mental functions such as hand-eye coordination, reflex response, and the processing of visual cues. One much-cited study of video gaming, published in *Nature* in 2003, revealed that after just 10 days of playing action games on computers, a group of young people had significantly increased the speed with which they could shift their visual focus among different images and tasks. Veteran game players were also found to be able to identify more items in their visual field than novices could. The authors of the study concluded that "although video-game playing may seem to be rather mindless, it is capable of radically altering visual attentional processing" (Green and Bavelier 2003).

While experimental evidence is sparse, it seems only logical that web searching and browsing would also strengthen brain functions related to certain kinds of fast-paced problem solving, particularly those involving the recognition of patterns in a welter of data. Through the repetitive evaluation of

links, headlines, text snippets, and images, we should become more adept at quickly distinguishing among competing informational cues, analyzing their salient characteristics, and judging whether they'll have practical benefit for whatever task we're engaged in or goal we're pursuing. One British study of the way women search for medical information online indicated that the speed with which they were able to assess the probable value of a web page increased as they gained familiarity with the Net (Sillence et al. 2007). It took an experienced browser only a few seconds to make an accurate judgment about whether a page was likely to have trustworthy information.

Other studies suggest that the kind of mental calisthenics we engage in online may lead to a small expansion in the capacity of our working memory (Klingberg 2009). That, too, would help us become more adept at juggling data. Such research "indicates that our brains learn to swiftly focus attention, analyze information, and almost instantaneously decide on a go or no-go decision," says Gary Small. He believes that as we spend more time navigating the vast quantity of information available online, "many of us are developing neural circuitry that is customized for rapid and incisive spurts of directed attention" (Small and Vorgan 2008: 21). As we practice browsing, surfing, scanning, and multitasking, our plastic brains may well become more facile at those tasks.

The importance of such skills shouldn't be taken lightly. As our work and social lives come to center on the use of electronic media, the faster we're able to navigate those media and the more adroitly we're able to shift our attention among online tasks, the more valuable we're likely to become as employees and even as friends and colleagues. As the writer Sam Anderson put it in "In Defense of Distraction," a 2009 article in *New York* magazine, "Our jobs depend on connectivity" and "our pleasure-cycles — no trivial matter — are increasingly tied to it." The practical benefits of web use are many, which is one of the main reasons we spend so much time online. "It's too late," argues Anderson, "to just retreat to a quieter time" (Anderson 2009).

He's right, but it would be a serious mistake to look narrowly at the Net's benefits and conclude that the technology is making us more intelligent. Jordan Grafman, head of the cognitive neuroscience unit at the National Institute of Neurological Disorders and Stroke, explains that the constant shifting of our attention when we're online may make our brains more nimble when it comes to multitasking, but improving our ability to multitask actually hampers our ability to think deeply and creatively. "Does optimizing for multitasking result in better functioning — that is, creativity, inventiveness, productiveness? The answer is, in more cases than not, no," says Grafman. "The more you multitask, the less deliberative you become; the less able to think and reason out a problem." You become, he argues, more likely to rely on conventional ideas and solutions rather than challenging them with original lines of thought (Tapscott 2009: 108-109). David Meyer, a University of Michigan neuroscientist and one of the leading experts on multitasking, makes a similar point. As we gain more experience in rapidly shifting our attention, we may "overcome some of the inefficiencies" inherent in multitasking, he says, "but except in rare circumstances, you can train until you're blue in the face and you'd never be as good as if you just focused on one thing at a time" (Jackson 2008: 70-80). What we're doing when we multitask "is learning to be skillful at a superficial level" (Begley and Interlandi 2008). The Roman philosopher Seneca may have put it best 2,000 years ago: "To be everywhere is to be nowhere."


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The mental functions that are losing the "survival of the busiest" brain cell battle are those that support calm, linear thought.

In an article published in *Science* in early 2009, Patricia Greenfield, a prominent developmental psychologist who teaches at UCLA, reviewed more than 50 studies of the effects of different types of media on people's intelligence and learning ability. She concluded that "every medium develops some cognitive skills at the expense of others." Our growing use of the Net and other screen-based technologies has led to the "widespread and sophisticated development of visual-spatial skills." We can, for example, rotate objects in our minds better than we used to be able to. But our "new strengths in visual-spatial intelligence" go hand in hand with a weakening of our capacities for the kind of "deep processing" that underpins "mindful knowledge acquisition, inductive analysis, critical thinking, imagination, and reflection" (Greenfield 2009: 69-71). The Net is making us smarter, in other words, only if we define intelligence by the Net's own standards. If we take a broader and more traditional view of intelligence —

if we think about the depth of our thought rather than just its speed — we have to come to a different and considerably darker conclusion.

Given our brain's plasticity, we know that our online habits continue to reverberate in the workings of our synapses when we're not online. We can assume that the neural circuits devoted to scanning, skimming, and multitasking are expanding and strengthening, while those used for reading and thinking deeply, with sustained concentration, are weakening or eroding. In 2009, researchers from Stanford University found signs that this shift may already be well under way. They gave a battery of cognitive tests to a group of heavy media multitaskers as well as a group of relatively light multitaskers. They found that the heavy multitaskers were much more easily distracted by "irrelevant environmental stimuli," had significantly less control over the contents of their working memory, and were in general much less able to maintain their concentration on a particular task. Whereas the infrequent multitaskers exhibited relatively strong "top-down attentional control," the habitual multitaskers showed "a greater tendency for bottom-up attentional control," suggesting that "they may be sacrificing performance on the primary task to let in other sources of information." Intensive multitaskers are "suckers for irrelevancy," commented Clifford Nass, the Stanford professor who led the research. "Everything distracts them" (Ophar, Nass, and Wagner 2009). Michael Merzenich offers an even bleaker assessment. As we multitask online, he says, we are "training our brains to pay attention to the crap." The consequences for our intellectual lives may prove "deadly" (Merzenich 2009).

The Roman philosopher Seneca may have put it best 2,000 years ago: "To be everywhere is to be nowhere."

The mental functions that are losing the "survival of the busiest" brain cell battle are those that support calm, linear thought — the ones we use in traversing a lengthy narrative or an involved argument, the ones we draw on when we reflect on our experiences or contemplate an outward or inward phenomenon. The winners are those functions that help us speedily locate, categorize, and assess disparate bits of information in a variety of forms, that let us maintain our mental bearings while being bombarded by stimuli. These functions are, not coincidentally, very similar to the ones performed by computers, which are programmed for the high-speed transfer of data in and out of memory. Once again, we seem to be taking on the characteristics of a popular new intellectual technology. K

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