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AUTHOR NICHOLAS CARR: THE WEB SHATTERS FOCUS, REWIRES BRAINS

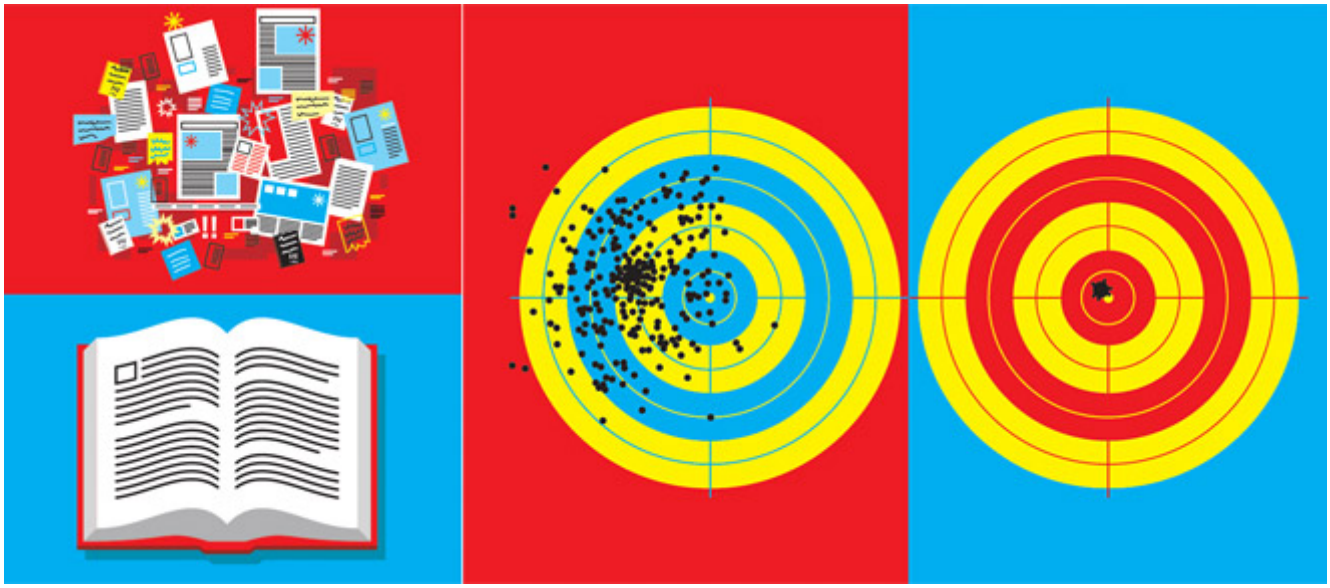

Illustration: I-dopa

DURING THE WINTER of 2007, a UCLA professor of psychiatry named Gary Small recruited six volunteers—three experienced Web surfers and three novices—for a study on brain activity. He gave each a pair of goggles onto which Web pages could be projected. Then he slid his subjects, one by one, into the cylinder of a whole-brain magnetic resonance imager and told them to start searching the Internet. As they used a handheld keypad to Google various preselected topics—the nutritional benefits of chocolate, vacationing in the Galapagos Islands, buying a new car—the MRI scanned their brains for areas of high activation, indicated by increases in blood flow.

The two groups showed marked differences. Brain activity of the experienced surfers was far more extensive than that of the newbies, particularly in areas of the prefrontal cortex associated with problem-solving and decisionmaking. Small then had his subjects read normal blocks of text projected onto their goggles; in this case, scans revealed no significant difference in areas of brain activation between the two groups. The evidence suggested, then, that the

distinctive neural pathways of experienced Web users had developed because of their Internet use.

The most remarkable result of the experiment emerged when Small repeated the tests six days later. In the interim, the novices had agreed to spend an hour a day online, searching the Internet. The new scans revealed that their brain activity had changed dramatically; it now resembled that of the veteran surfers. “Five hours on the Internet and the naive subjects had already rewired their brains,” Small wrote. He later repeated all the tests with 18 more volunteers and got the same results.

When first publicized, the findings were greeted with cheers. By keeping lots of brain cells buzzing, Google seemed to be making people smarter. But as Small was careful to point out, more brain activity is not necessarily better brain activity. The real revelation was how quickly and extensively Internet use reroutes people’s neural pathways. “The current explosion of digital technology not only is changing the way we live and communicate,” Small concluded, “but is rapidly and profoundly altering our brains.”

What kind of brain is the Web giving us? That question will no doubt be the subject of a great deal of research in the years ahead. Already, though, there is much we know or can surmise—and the news is quite disturbing. Dozens of studies by psychologists, neurobiologists, and educators point to the same conclusion: When we go online, we enter an environment that promotes cursory reading, hurried and distracted thinking, and superficial learning. Even as the Internet grants us easy access to vast amounts of information, it is

turning us into shallower thinkers, literally changing the structure of our brain.

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 monitors would be a boon to learning. Hypertext would strengthen critical thinking, the argument went, by enabling students to switch easily between different viewpoints. Freed from the lockstep reading demanded by printed pages, readers would make all sorts of new intellectual connections between diverse works. The hyperlink would be a technology of liberation.

By the end of the decade, the enthusiasm was turning to skepticism. Research was painting a fuller, very different picture of the cognitive effects of hypertext. Navigating linked documents, it turned out, entails a lot of mental calisthenics —evaluating hyperlinks, deciding whether to click, adjusting to different formats—that are extraneous to the process of reading. Because it disrupts concentration, such activity weakens comprehension. A 1989 study showed that readers tended just to click around aimlessly when reading something that included hypertext links to other selected pieces of information. A 1990 experiment revealed that some "could not remember what they had and had not read."

Even though the World Wide Web has made hypertext ubiquitous and presumably less startling and unfamiliar, the cognitive problems remain. 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. In a 2001 study, two scholars in Canada asked 70 people to read "The Demon Lover," a short story by Elizabeth Bowen. One group read it in a traditional linear-text format; they'd read a passage and click the word *next* to move ahead. A second group read a version in which they had to click on highlighted words in the text to move ahead. It took the hypertext readers longer to read the document, and they were seven times more likely to say they found it confusing. Another researcher, Erping Zhu, had people read a passage of digital prose but varied the number of links appearing in it. She then gave the readers a multiple-choice quiz and had them write a summary of what they had read.

She found that comprehension declined as the number of links increased—whether or not people clicked on them. After all, whenever a link appears, your brain has to at least make the choice not to click, which is itself distracting.

A 2007 scholarly review of hypertext experiments concluded that jumping between digital documents impedes understanding. And if links are bad for concentration and comprehension, it shouldn't be surprising that more recent research suggests that links surrounded by images, videos, and advertisements could be even worse.

In a study published in the journal *Media Psychology*, researchers had more than 100 volunteers watch a presentation about the country of Mali, played through a Web browser. Some watched a text-only version. Others watched a version that incorporated video. Afterward, the subjects were quizzed on the material. Compared to the multimedia viewers, the text-only viewers answered significantly more questions correctly; they also found the presentation to be more interesting, more educational, more understandable, and more enjoyable.

The depth of our intelligence hinges on our ability to transfer information from working memory, the scratch pad of consciousness, to long-term memory, the mind's filing system. When facts and experiences enter our long-term memory, we are able to weave them into the complex ideas that give richness to our thought. But the passage from working memory to long-term memory also forms a bottleneck in our brain. Whereas long-term memory has an almost unlimited capacity, working memory can hold only a relatively small amount of information at a time. And that short-term storage is fragile: A break in our attention can sweep its contents from our mind.

Imagine filling a bathtub with a thimble; that's the challenge involved in moving information from working memory into long-term memory. When we read a book, the information faucet provides a steady drip, which we can control by varying the pace of our reading. Through our single-minded concentration on the text, we can transfer much of the information, thimbleful by thimbleful, into long-term memory and forge the rich associations essential to the creation of knowledge and wisdom.

On the Net, we face many information faucets, all going full blast. Our little

thimble overflows as we rush from tap to tap. We transfer only a small jumble of drops from different faucets, not a continuous, coherent stream.

Psychologists refer to the information flowing into our working memory as our cognitive load. When the load exceeds our mind's ability to process and store it, we're unable to retain the information or to draw connections with other memories. We can't translate the new material into conceptual knowledge. Our ability to learn suffers, and our understanding remains weak. That's why the extensive brain activity that Small discovered in Web searchers may be more a cause for concern than for celebration. It points to cognitive overload.

The Internet is an interruption system. It seizes our attention only to scramble it. There's the problem of hypertext and the many different kinds of media coming at us simultaneously. There's also the fact that numerous studies—including one that tracked eye movement, one that surveyed people, and even one that examined the habits displayed by users of two academic databases—show that we start to read faster and less thoroughly as soon as we go online. Plus, the Internet has a hundred ways of distracting us from our onscreen reading. Most email applications check automatically for new messages every five or 10 minutes, and people routinely click the Check for New Mail button even more frequently. Office workers often glance at their inbox 30 to 40 times an hour. Since each glance breaks our concentration and burdens our working memory, the cognitive penalty can be severe.

The penalty is amplified by what brain scientists call switching costs. Every time we shift our attention, the brain has to reorient itself, further taxing our mental resources. Many studies have shown that switching between just two tasks can add substantially to our cognitive load, impeding our thinking and increasing the likelihood that we'll overlook or misinterpret important information. On the Internet, where we generally juggle several tasks, the switching costs pile ever higher.

The Net's ability to monitor events and send out messages and notifications automatically is, of course, one of its great strengths as a communication technology. We rely on that capability to personalize the workings of the system, to program the vast database to respond to our particular needs,

interests, and desires. We want to be interrupted, because each interruption—email, tweet, instant message, RSS headline—brings us a valuable piece of information. To turn off these alerts is to risk feeling out of touch or even socially isolated. The stream of new information also plays to our natural tendency to overemphasize the immediate. We crave the new even when we know it's trivial.

And so we ask the Internet to keep interrupting us in ever more varied ways. We willingly accept the loss of concentration and focus, the fragmentation of our attention, and the thinning of our thoughts in return for the wealth of compelling, or at least diverting, information we receive. We rarely stop to think that it might actually make more sense just to tune it all out.

The mental consequences of our online info-crunching are not universally bad. Certain cognitive skills are strengthened by our use of computers and the Net. These tend to involve more primitive mental functions, such as hand-eye coordination, reflex response, and the processing of visual cues. One much-cited study of videogaming, published in *Nature* in 2003, revealed that after just 10 days of playing action games on computers, a group of young people had significantly boosted the speed with which they could shift their visual focus between various images and tasks.

It's likely that Web browsing also strengthens brain functions related to fast-paced problem-solving, particularly when it requires spotting patterns in a welter of data. A British study of the way women search for medical information online indicated that an experienced Internet user can, at least in some cases, assess the trustworthiness and probable value of a Web page in a matter of seconds. The more we practice surfing and scanning, the more adept our brain becomes at those tasks. (Other academics, like Clay Shirky, maintain that the Web provides us with a valuable outlet for a growing "cognitive surplus"; see Cognitive Surplus: The Great Spare-Time Revolution

But it would be a serious mistake to look narrowly at such benefits and conclude that the Web is making us smarter. In a Science article published in early 2009, prominent developmental psychologist Patricia Greenfield reviewed more than 40 studies of the effects of various types of media on

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, she wrote, has led to the "widespread and sophisticated development of visual-spatial skills." But those gains go hand in hand with a weakening of our capacity for the kind of "deep processing" that underpins "mindful knowledge acquisition, inductive analysis, critical thinking, imagination, and reflection."

We know that the human brain is highly plastic; neurons and synapses change as circumstances change. When we adapt to a new cultural phenomenon, including the use of a new medium, we end up with a different brain, says Michael Merzenich, a pioneer of the field of neuroplasticity. That means our online habits continue to reverberate in the workings of our brain cells even when we're not at a computer. We're exercising the neural circuits devoted to skimming and multitasking while ignoring those used for reading and thinking deeply.

Last year, researchers at Stanford 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 ones. They discovered that the heavy multitaskers were much more easily distracted, had significantly less control over their working memory, and were generally much less able to concentrate on a task. Intensive multitaskers are "suckers for irrelevancy," says Clifford Nass, one professor who did the research. "Everything distracts them." Merzenich offers an even bleaker assessment: As we multitask online, we are "training our brains to pay attention to the crap."

There's nothing wrong with absorbing information quickly and in bits and pieces. We've always skimmed newspapers more than we've read them, and we routinely run our eyes over books and magazines to get the gist of a piece of writing and decide whether it warrants more thorough reading. The ability to scan and browse is as important as the ability to read deeply and think attentively. The problem is that skimming is becoming our dominant mode of thought. Once a means to an end, a way to identify information for further study, it's becoming an end in itself—our preferred method of both learning and analysis. Dazzled by the Net's treasures, we are blind to the damage we may be

doing to our intellectual lives and even our culture.

What we're experiencing is, in a metaphorical sense, a reversal of the early trajectory of civilization: We are evolving from cultivators of personal knowledge into hunters and gatherers in the electronic data forest. In the process, we seem fated to sacrifice much of what makes our minds so interesting.

Adapted from The Shallows: What the Internet Is Doing to Our Brains, *copyright©2010 Nicholas Carr to be published by W.W. Norton and Company in June.* **Nicholas Carr***(ncarr@mac.com) is also the author of* The Big Switch and Does IT Matter?

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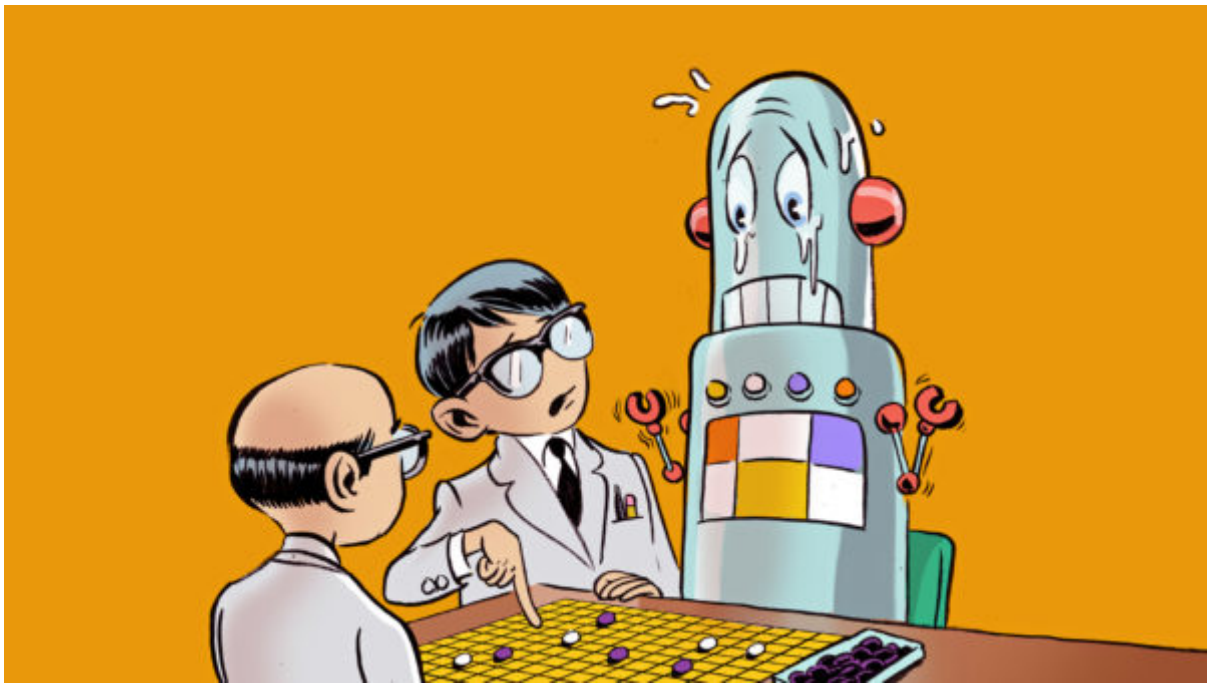

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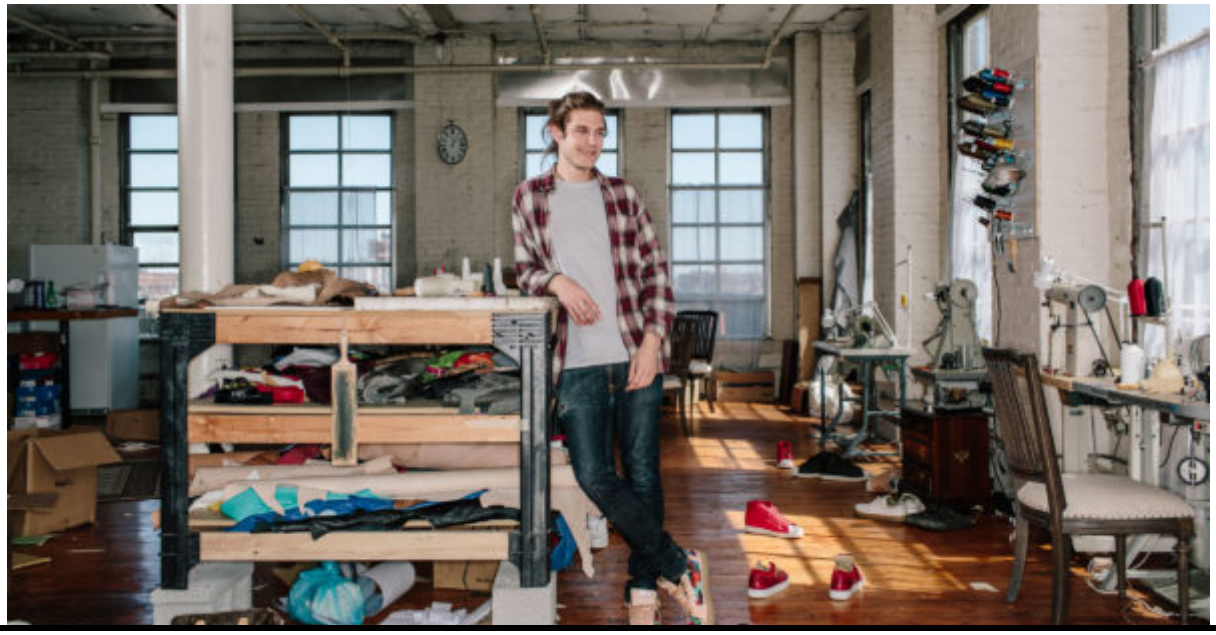

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