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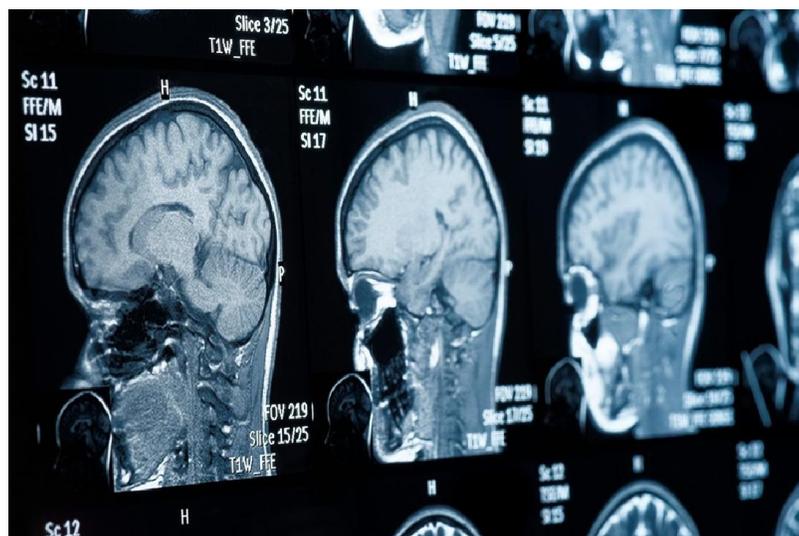
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THE SATURDAY ESSAY

Our Amazingly Plastic Brains

Mental and physical exercise can keep the brain fit and help it recover capacities lost to disease and trauma



As people reach middle age, exercising the brain and the body to which it is attached—keeping both active—becomes more important. *PHOTO: GETTY IMAGES*

By **NORMAN DOIDGE**

Feb. 6, 2015 5:34 p.m. ET

Can the brain heal and preserve itself—or even improve its functioning—as we get older? For some time, many scientists have tended to think of our brains as machines, most commonly as computers, destined to break down over time under the strain of age and use. In recent years, however, research in neuroscience has begun to show the inadequacy of this metaphor for describing the physiology of the brain. It turns out that our brains, like our bodies in

general, are far more likely to waste away from underuse than to wear down from overuse.

As people reach middle age, exercising the brain and the body to which it is attached—keeping both active—becomes more important. It is one of the few reliable ways to offset the natural wasting process and the damaging influence of our unnaturally sedentary modern lives. It also points to new possibilities for the brain to heal itself in the face of disease and trauma.

For decades, physicians and scientists generally believed that the prognosis for most brain problems was grim. The standard view was that the brain had evolved to be so complex and specialized that we had to pay a price for its sophistication: It couldn't repair or restore itself with replacement parts, as was possible with other organs, such as the skin, liver and blood.

That view fit with, and partly stemmed from, an image that had prevailed since the days of the great French philosopher and scientist René Descartes, who described the brain as a glorious machine with discrete parts. Descartes's heirs argued that each of these parts performed a single mental function in a single location. If a part was damaged—by a genetic fault, or stroke, or injury or disease—it was assumed that the body had no resources of its own to deal with the problem: After all, machines cannot repair themselves or spontaneously grow new parts.

Once the electrical nature of the brain was delineated in the 19th century, scientists began speaking of it as a grander sort of machine, an electrical one, with “circuits”—a metaphor still very much with us. They came to see its circuits as analogous to those of electronic gadgets—unchangeable or “hard-wired.”

As the machine metaphor evolved, neuroscientists took to describing the brain as a computer. This “master analogy,” as computer scientist David Gelernter calls it (in criticizing this view), encourages us to see thought as “software” and the brain's structure as “hardware.”

The unhappy practical implication of this view, for anyone wishing to maintain his or her brain, is clear: Hardware inevitably degenerates with time and use. The rule for a machine is, “Use it *and* lose it.” Many clinicians under the sway of this analogy saw patients' attempts to resist their brains' decline through activity and mental exercise as a harmless waste of time.

Fortunately, a growing body of research suggests that this older view is wrong. It

seems that a more accurate rule for our brains is “Use it *or* lose it.”

In the late 1970s, research by Mark Rosenzweig of the University of California at Berkeley and Michael Merzenich of the University of California at San Francisco and others began to show that the brain’s circuitry changes microscopically with experience and activity. Dr. Rosenzweig and colleagues found that, with environmental stimulation, the brains of animals grew in key areas. Dr. Merzenich discovered that if an animal stopped using a body part, the brain area that processed sensory input from that part weakened or was taken over to perform another function. These findings have since been replicated many times.

The mainstream view in neuroscience and medicine today is that the living brain is actually “neuroplastic”—meaning that its “circuits” are constantly changing in response to what we actually do out in the world. As we think, perceive, form memories or learn new skills, the connections between brain cells also change and strengthen. Far from being hard-wired, the brain has circuits that very rapidly form, unform and reform.

This capacity is the foundation for the brain’s distinctive way of healing. If an area is damaged, new neurons can often take over old tasks. Nor are we just our neurons. Our memories and experiences are also encoded in the patterns of electrical energy produced by our brain cells, like a musical score. As with an orchestra, when one member of the string section is sick, the show can still go on if a replacement has access to the musical score.

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This new “plastic” understanding has major practical implications for how we treat brain problems and maintain brain health. And it has led to some surprising discoveries.

Consider dementia, which in some form affects some 15% of people in the U.S. over age 70 and advances rapidly as we age. A brain with Alzheimer’s, the most common form of dementia, turns out, by various measures, to be a brain that is

losing its overall plasticity. It shrinks and loses connections. But a growing body of research has found that exercise, both mental and physical, can lower the risk of experiencing dementia.

Last year, Peter Elwood and a team from the Cochrane Institute of Primary Care and Public Health at Cardiff University in the U.K. released results from the most detailed study ever done on the effect of lifestyle and exercise on the risk of getting dementia. The researchers followed 2,235 men—almost all the male inhabitants of Caerphilly, Wales, with initial ages between 45 and 59 years old—for 30 years.

They found that men who consistently did a few things reduced their risk for cognitive decline and dementia by a staggering 60%. These activities included eating a healthy diet (at least three to four servings of fruits and vegetables a day); maintaining a normal weight, with a body-mass index of 18 and 25; limiting alcohol to about a glass of wine a day; and not smoking.

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But the activity with the biggest impact on risk was walking at least 2 miles a day, biking 10 miles a day or engaging in some other regular, vigorous physical exercise. All five of these factors have been found in other studies to promote the general health of two types of cells in the brain: neurons and glial cells (which interact with and protect neurons).

Imagine if there were a drug that could reduce the risk of dementia by 60%. It would be the most talked-about drug in history, but this astonishing finding has been fairly quietly received.

One reason is that many people assume that Alzheimer's disease is "all in your genes." But as neurologist and dementia researcher Tiffany Chow of the Rotman Research Institute and the University of Toronto points out, environmental factors "interact with...genetic makeup to eventually allow or deny dementia a

foothold.” Even having multiple copies of the genetic materials associated with risk, Dr. Chow points out, “is not sufficient to produce Alzheimer’s disease.” For the majority of people, how they live matters.

The research in Wales followed at least 10 other studies showing that exercise in midlife was associated or correlated with lower rates of dementia—and that a lack of regular exercise corresponded with higher rates of dementia.

Another recent study—a randomized, controlled trial by Kirk Erickson of the University of Pittsburgh and colleagues published in the Proceedings of the National Academy of Sciences—shows that those without dementia who did aerobic exercise for a year showed significant hippocampal enlargement. The hippocampus is the brain region that turns short-term memories into long-term ones, and it is often the first to degenerate in Alzheimer’s cases and with age in general. Earlier studies showed aerobic exercise increased the brain’s gray and white matter in the frontal lobes, areas involved in planning and goal-directed activity.

How does this form of healing work? Exercise triggers the growth of new brain cells in the hippocampus. It also triggers the release of “neurotrophic growth factors”—a kind of brain fertilizer, helping the brain to grow, maintain new connections and stay healthy.



PHOTO: GETTY IMAGES

Frederick Gage of the Salk Institute, co-discoverer of stem cells in the brain, has suggested that new cells arise from long walks because, in an evolutionary sense, our bodies associate the exertion with moving from an existing territory, which had perhaps become depleted of food or too dangerous, to a new, unexplored territory whose details must be learned. In anticipation, the brain releases new cells and growth factors, which create a more plastic state and make possible new neural connections. This may be one of the mechanisms by which exercise helps to protect against diseases such as Alzheimer’s.

Recent studies have also found that exercise can reduce the symptoms of Parkinson’s—a degenerative disease that causes patients to gradually lose control of their muscles. Parkinson’s treatment has primarily focused on medication, with exercise as something of a distant runner-up.

But in 2011, a study of these issues was published in the journal *Neurology*. J. Eric Ahlskog of the Mayo Clinic reviewed the available evidence about exercise

and Parkinson's, in animals and humans. Vigorous exercise, for purposes of the study, included walking, swimming and "physical activity sufficient to increase heart rate and the need for oxygen." He concluded that exercise deserved a "central place" in the treatment of Parkinson's.

A 2014 randomized study of Parkinson's patients at the University of Iowa, led by researcher Ergun Uc, found that walking three times a week for 45 minutes for six months improved patients' mood and Parkinsonian movement symptoms; the exercise also decreased their fatigue. Though the patients were on anti-Parkinson's medication, the improvements could not be attributed to medication alone.

Parkinson's patients are caught in a tightening noose. They may be helped by fast walking, but fast walking is precisely what they can no longer easily do. And the Parkinson's patient who cannot walk does not "stay still"—his disease gets worse. Because our plastic brains are "use it or lose it" organs, when walking becomes more difficult, walking less will cause whatever walking circuits the patient still has to wither from disuse.

When people with dormant brain circuits try to walk, they fail, "learn" that they can't walk and stop trying. This is called "learned nonuse," a phenomenon first seen in human beings who have suffered a stroke—caused by a blood clot or a bleed that cuts off the blood supply and oxygen to brain tissue and killing it.

We have known for more than a century that, after a stroke, the brain enters a state of shock: Neurons die, chemicals leak out of some cells and harm others, inflammation is very active, and blood flow around the dead tissue is interrupted. All of these events disrupt functioning not just where the stroke occurred but throughout the brain. The period typically lasts six weeks or longer.

Physicians once treated such dire problems by waiting six weeks to see what mental functions their stroke patients still had. Since conventional medical wisdom held that the brain couldn't "rewire" itself or develop new connections, physicians just wanted to discover which cognitive abilities remained after the shock wore off. The rehabilitation that patients underwent merely attempted to reawaken whatever circuits had been spared.

But the plasticity of the brain provides better options. Edward Taub, a neuroscientist at the University of Alabama at Birmingham who discovered "learned nonuse," has had striking results with patients who have lost the use of

limbs from strokes and haven't gotten better with conventional rehabilitation. He puts the patient's good arm in a sling (so they can't use it), for instance, and then incrementally and intensively trains the paralyzed or partially paralyzed arm.

Brain-scan studies show that when patients recover under Dr. Taub's treatment, neurons adjacent to the injury begin to take over from the damaged or dead neurons. More recently, the approach has worked with stroke patients who can no longer speak and with movement problems from multiple sclerosis, cerebral palsy and even movement problems that occur after radiation to the brain for cancer. Learned nonuse seems to occur in response to many brain problems, so dormant circuits, awaiting to be revived, are far more common than has been generally appreciated.

Among the most exciting new neuroplastic treatments are those that deal with "the noisy" brain—that is, neurons that fire out of sync or at the wrong rates in conditions like multiple sclerosis and Parkinson's disease, but also in traumatic brain injuries, learning disorders, conditions on the autism spectrum and some cases of chronic pain.

A range of noninvasive methods has yielded radical improvements in all these diseases, allowing scientists and clinicians to "resynchronize" the noisy brain. Our brains work on patterns of electrical energy, and we can change the patterns of brain-firing with sensory input. When you hear a loud pounding beat, for instance, your neurons fire in sync to that frequency, a process called "entrainment."

Using sound frequencies passed into the ears (which convert patterns of sound energy into patterns of electrical energy), it has been possible to cure some learning disorders and developmental delays, as well as to radically improve the lives of some autistic children. Scientists and doctors using mild forms of electricity to turn on touch receptors in the tongue have been able to reduce the symptoms of MS, Parkinson's and brain injuries—and even to cure some strokes.

Clinical work in Toronto and studies at Harvard and in Israel have shown that low-intensity lasers applied to the back of the neck can diminish stroke and brain-injury symptoms. And new forms of "conscious walking" that allow Parkinson's patients to learn to use healthy parts of their brains to take over from damaged areas can sometimes get them moving again.

The basic neuroplastic principle of "use it or lose it" and the benefit of forming

new brain connections through intensive learning also apply to people without brain problems. Physical exercise produces some new cells in the memory system, but mental exercise preserves and strengthens existing connections in the brain, giving a person a “cognitive reserve” to fend off future losses and to perfect skills.

Brain exercises developed by the neuroscientist Dr. Merzenich have been evaluated in a National Institutes of Health study, published by George Rebok of the Johns Hopkins School of Medicine and colleagues in the *Journal of the American Geriatrics Society*. People who did the brain exercises—called Brain HQ—showed benefits 10 years later. They didn’t just improve on the brain exercises; their cognitive function improved in everyday life. Earlier studies showed that the exercises increased a person’s mental sharpness, so they could process information with the speed and accuracy they had when they were 10 years younger.

We still have a lot to learn about the brain and its powers of recovery, of course. But increasingly we have the evidence to conclude that we have been seeing our brains the wrong way for too long. Metaphors often conceal as much as they reveal. One day, we may well marvel at how odd it was that, for several centuries, we chose to view our ever-changing, activity-craving, animate brains as fixed, passive, inanimate machines.

Dr. Doidge teaches in the University of Toronto’s department of psychiatry and is on the research faculty at Columbia University’s Center for Psychoanalytic Training and Research. His latest book is “The Brain’s Way of Healing” (Viking), from which this is adapted.

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