Brutal Truths About the Aging Brain

A graying world will have more of the experience that comes with age. It will also be slower, fuzzier, more forgetful, and just a bit hard of hearing.

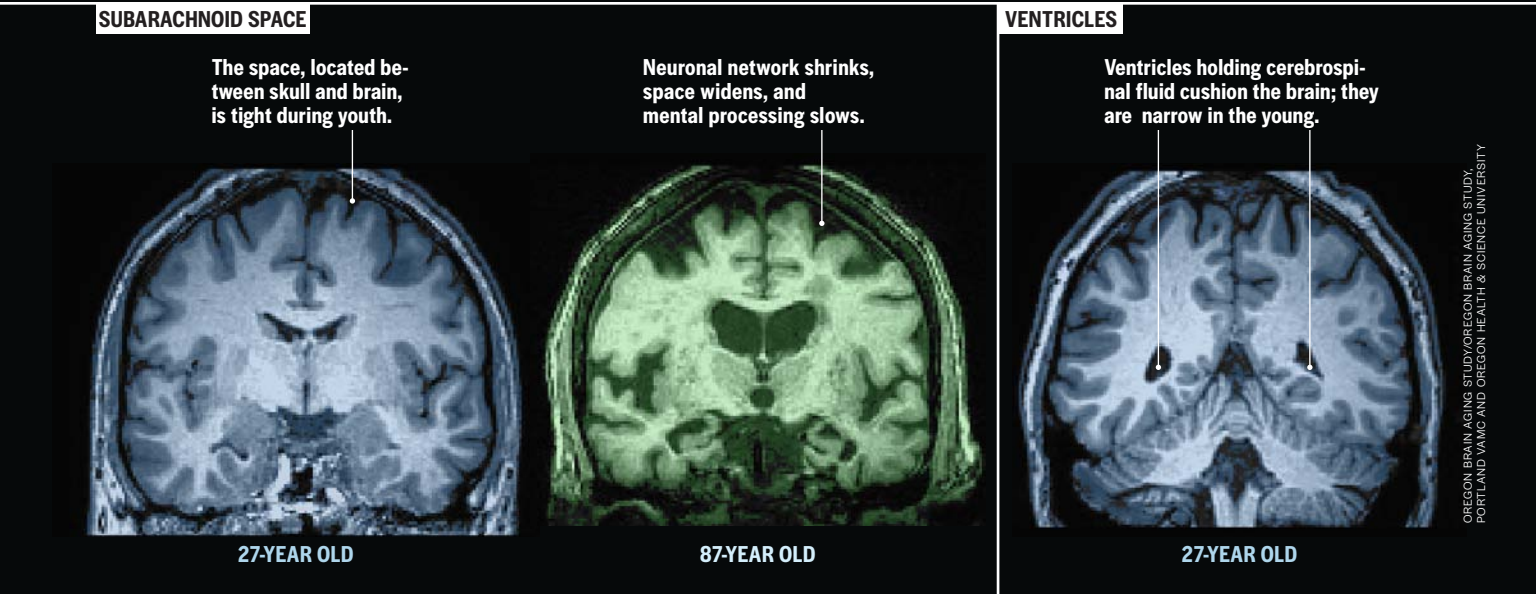
by ROBERT EPSTEIN

AS A GRADUATE STUDENT AT HARVARD University, I worked with one of the most influential behavioral scientists of all time, B. F. Skinner. Beginning in the summer of 1977, we worked together nearly every day for more than four years, designing experiments and chatting about literature, philosophy, and the latest research. Although we were 50 years apart in age, we were also friends. We saw *Star Wars* together, had lunch frequently in Harvard Square, and swam in his backyard pool each summer. "Fred" (from Burrhus Frederic) Skinner was the happiest, most creative, most productive person I have ever known. He was also, needless to say, quite smart.

But the septuagenarian I knew was well past his intellectual peak. One day he gave me a set of tapes of a famous debate he had had with psychologist Carl Rogers in 1962. The Skinner on those tapes seemed sharper, faster, and even wittier than the man I knew. Was I imagining this?

Recently, Gina Kirkish, a student at the University of California, San Diego, and I analyzed tapes of three comparable samples of Skinner's speech: that 1962 debate, a 1977 debate, and a speech he gave from notes shortly before he died in 1990 at age 86. We found that the speech rate dropped significantly over time, from 148 words per minute in the first sample to 137 in the second to 106 in the third—an overall

Tale of the Scans: A Mind in Decline



decrease of more than 28 percent.

Skinner's memory and analytical skills were also declining during the years when I knew him. Sometimes he had no recollection of a conversation we had had only days before. When I tried to talk with him about technical papers he had published early in his career, he often didn't seem to understand what he had written. And he had no patience for anything mathematical, even his own equations. On the other hand, Skinner was still much smarter than most of the people I knew my own age. When you fall from a high enough cliff, you remain far above ground for a very long time.

The sad truth is that even normal aging has a devastating effect on our ability to learn and remember, on the speed with which we process information, and on our ability to reason. Recent studies suggest that the total loss in brain volume due to atrophy—a wasting away of tissue caused by cell degeneration—between our teen years and old age is 15 percent or more, which means that by the time we're in our seventies, our brains have shrunk to the size they were when we were between 2 and 3 years old. Unfortunately, most of the loss is in gray matter, the critically important part of the brain composed of neurons, the cells that transmit the signals that keep us breathing and thinking.

Contrary to what scientists long believed, only about 10 percent of our neurons die during adulthood. The real loss is in the network of connections—the "dendritic trees" that allow a single neuron to be connected to a thousand others. Over the years, 25 percent or more of this network disappears. According to William Jagust, a neuroscientist at the University of California, Berkeley, adults are also losing dopamine, a critical neurotransmitter (the type of chemical involved in transmitting signals between neurons), at the rate of 5 to 8 percent per decade. "By age 80," Jagust says, "you've lost 40 percent or so of dopamine function. When you think about it, it's remarkable that old people can do so well."

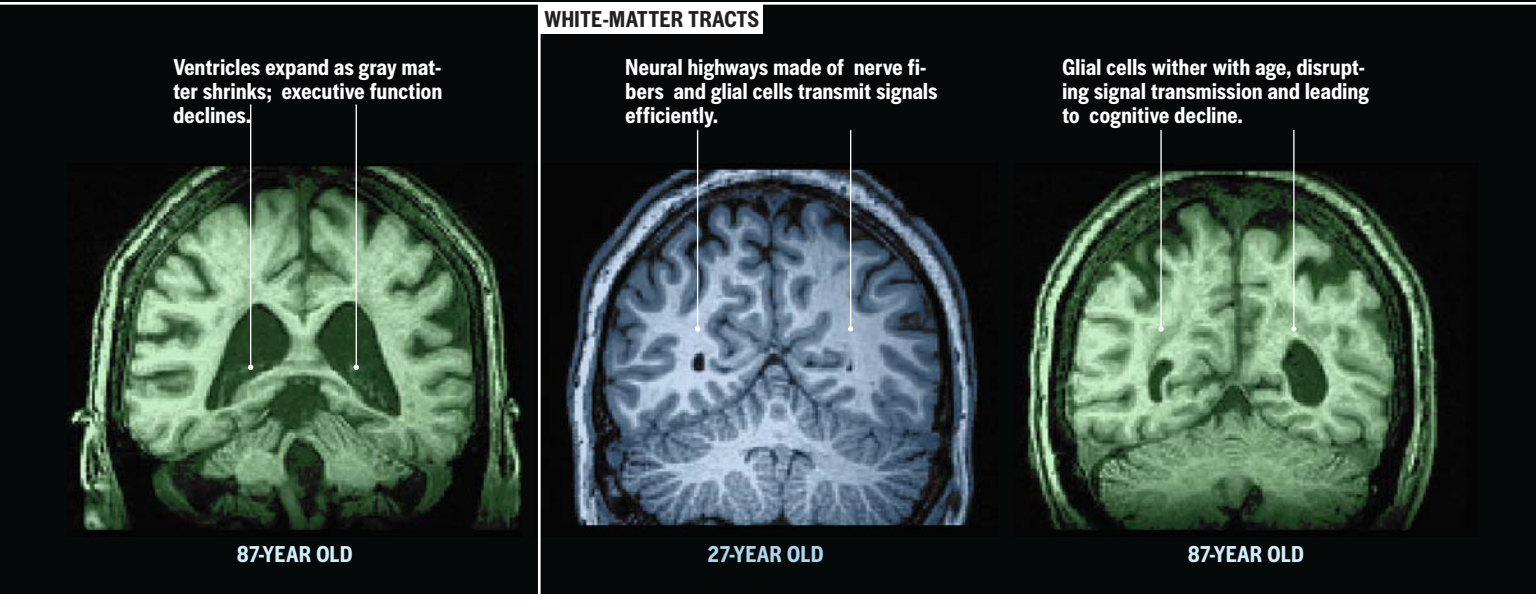
Shrinkage, dopamine depletion, and lost dendritic connections are not the only problems facing the aging brain. Myelin, a substance that insulates neurons, deteriorates, and the number of nerve fibers that carry messages throughout the central nervous system also decreases. Chemical problems—such as an increase in calcium conductance, which might impair neuronal communication—also become more common in older brains, as do problems with gene expression and protein production.

With the global population of people over 80 expected to more than quadruple to nearly 400 million by 2050, the aging brain will become an increasingly big headache for humankind. Here are four cognitive systems that tend to decline as we age. Get used to these changes. You'll be seeing a lot more of them in the future.

1. Senses

Our ability to learn and remember is limited by the accuracy of our senses, our points of contact with the world. But vision, hearing, touch, smell, and taste are not just detection systems. The sense organs also comprise a primitive kind of memory, a temporary storage system or "buffer" for the brain. Much of the input to our sense organs reverberates in receptors, and that reverberation allows even weak stimuli—for example, images flashed so quickly that we have no conscious awareness of them—to impact decisions we make later on. Without the buffering ability of our sense organs, a great deal of information about the world would be lost to us. Unfortunately, as we age, our sensory systems deteriorate, and at the extreme, we become completely insensitive to a wide range of input. For example, high-pitched tones that we can detect at a mere 30 decibels when we are young have to be boosted to an ear-splitting 90 decibels for the elderly to hear. (Physics buffs: That's about a million

Brains atrophy as they age, causing a wide variety of deficits. Neuroscientist Jeffrey Kaye of the Oregon Health & Science University used MRI scans (like those below) to track this process. He says the shrinkage occurs as blood flow slows, reducing oxygen and nutrients to cells in the brain. That leads to reduced ability to feed and repair neurons and associated cognitive decline. EMMA BRYCE



times the energy intensity.) And pupil size decreases as we age, so when it is dim, the elderly person's eyes pick up about a third as much light as people in their prime. Because the deterioration of sense organs limits our access to critical information—speech, text, music, street signs—thinking itself is impaired.

And loss of information is just part of the problem. Research by psychologist Monica Fabiani and her colleagues at the University of Illinois at Urbana-Champaign suggests that in older people the main problem might not be that the sense organ is rejecting input but rather that the brain itself is having trouble filtering out irrelevant information. In a recent study, Fabiani had people of various ages read a book while trying to ignore auditory tones piped through headphones. Overall, the older the individual, the more trouble he or she had ignoring the tones. "The background stimuli may flood your thinking with things that are irrelevant and that you cannot inhibit," Fabiani says. As a result, "you basically lose the capacity to perform tasks."

2. Memory

Most people think of human memory as a single system. But because different kinds of information are retained differently, experts speculate that distinct types of memory systems exist in the brain. Some information stays with us for only a short time—generally no more than a few seconds unless we do something with it. For example, if somebody tells you a phone number and you do not immediately repeat it, it will very likely disappear, never to return. Research suggests the existence of a short-term memory system, consisting in turn of two subsystems: immediate memory (the temporary storage system that holds on to information we don't process in some way) and working memory (a system that allows us to retain information as long as we keep using it).

As we age, our ability to process new information in working memory is severely compromised. In a typical test procedure for evaluating working memory, cognitive aging researcher Timothy Salthouse of the University of Virginia asked people to perform arithmetic computations while also trying to remember the last digit in each problem. People in their twenties were typically able to solve four or five of these problems in a row and still recall the final digits without error. With each decade, performance deteriorated; people in their seventies could typically solve no more than two such problems in a row and still get the final digits right.

One of the simplest ways to assess memory is to read test subjects a list of words and ask them, after a short time has passed, to repeat as many as they can. In a 1990 study, Hasker Davis and his colleagues at the University of Colorado found that people in their twenties could typically recall 90 percent of a list of 15 words after a short delay. With each additional decade of age, the percentage of words recalled decreased. People in their eighties could recall only about half the words.

3. Knowledge

Some information in our short-term memory system is consolidated into a long-term storage system, where it remains available to retrieve for months or years. If a memory of anything from a good meal to a coworker's name persists for 5 years, there is a good chance it will persist for another 40. But as we age, the degradation of sensory and working memory systems makes it increasingly difficult for us to transfer information into long-term storage. That's why, if you are over 50, you are more likely to

CONTINUED ON PAGE 76

The **Good News**, Such As It Is

Facing the specter of Alzheimer's disease, the most devastating and widespread manifestation of brain deterioration in old age, worried Baby Boomers have inspired whole catalogs of brain-fitness books and services. That's good news for publishers, vitamin companies, and computer game designers, but probably bad news for Boomers themselves. Elizabeth Zelinski, a gerontologist at the University of Southern California, told me she was appalled at the explosion of miracle cures on the market, adding bluntly, "There's no evidence that anything works." (There is some evidence that some interventions work very narrowly or for short periods of time, but generally speaking, the new industry makes outrageous claims.) And don't hold your breath waiting for neuroscience to rescue you from your upcoming decline. When I asked neuroscientist Eric Kandel, a Nobel Prize winner in medicine, how long it will be before we achieve some reasonable understanding of how memory actually works, he replied, "a hundred years."

On the bright side, some people appear to overcome the ravages of a rotting brain by recruiting new brain systems or structures to take over functions of old ones. Neuropsychologist Yaakov Stern of the Columbia University College of Physicians and Surgeons points out that upwards of 25 percent of people who function perfectly normally while alive have brains that show serious signs of Alzheimer's in autopsy. People with more education have lower rates of dementia, suggesting that brains that get more of a workout create reserves that kick in when frontline systems start to fail.

Kandel, now 82, appears to be one of those rare souls who has somehow managed to keep Father Time at bay. He remains active in research at Columbia University, and his extraordinary productivity and creativity are exemplified by his weighty 2012 book, *The Age of Insight: The Quest To Understand the Unconscious in Art, Mind, and Brain from Vienna 1900 to the Present*. Kandel's daughter, attorney Minouche Kandel, speculates that her father's clarity and energy result from an almost fanatical regimen of healthy food—mainly fish—and regular exercise. "He's lived this healthy lifestyle for as long as I can remember," she says, "and he was doing it long before it was popular."

Through some combination of luck, good genes, and a healthy lifestyle, it is possible, it seems, for a fortunate few to stay razor sharp well into old age. R. E.

CONTINUED FROM PAGE 50

remember the lyrics to a Beatles song than to any song you have heard in the past 20 years. To put this another way, our ability to learn new things is extraordinary when we are young and peaks in our teens. We can learn after that, but it becomes increasingly difficult. In an early study by psychologist Jeanne Gilbert, English speakers of different ages were asked to learn Turkish vocabulary words. People in their sixties learned 60 percent fewer words than young adults in their twenties who spent equal time and effort on the task.

One of the most frustrating experiences we have as we age is accessing a particular word from long-term memory—the so-called "word-finding" or "tip-of-the-tongue" problem. Deborah Burke, a psychology professor at Pomona College who has studied this phenomenon for more than 20 years, explains that old people suffer from a disconnect between the meaning of a word—which presumably tells you that it is the correct word to say right now—and the sound of that word. It is, she says, "the most irritating and disturbing cognitive problem" reported by older adults. We do not know what causes the disconnect.

4. Intelligence

We also get dumber as we age. IQ remains fairly stable, but that is because it is a relative measure—a quotient (the Q) that shows where we stand relative to people our own age. The problem is that raw scores on intelligence tests actually peak in our teens, remain high for a few years, and then decline throughout life; IQ remains fairly stable only because people decline at roughly the same rate. And yes, even geniuses decline. I recently asked Nobel Laureate James Watson, 84, when he reached his intellectual peak, and he replied, "Twenty, maybe 21—certainly before we found the DNA structure." That seminal work had been done when he was 25.

Intelligence, like memory, is divided into types that decline somewhat differently. Factual information is the basis of what is called crystallized intelligence, and much of the crystallized knowledge we acquire stays fairly strong at least into our sixties. However, fluid intelligence—our ability to reason—declines dramatically in most people, in large part because we get *slow*. Generally speaking, on tasks involving reasoning, what a 20-year-old can do in about half a second takes a healthy 80-year-old more than two seconds—if, that is, he or she can do it at all. As Douglas Powell of the Harvard Medical School puts it in his recent book, *The Aging Intellect*, "No other single mental ability declines as rapidly during the adult years as processing speed."

Neuroscientists tackle the decline in reasoning and working memory under an umbrella concept called executive function. Somewhere in the brain there seems to be a coach: a system or structure that schedules and prioritizes, garnering resources, redirecting attention, or switching tasks as needed. Adam Gazzaley, a neurology professor at the University of California, San Francisco, has conducted research documenting how that coaching ability declines as we age. For example, older people are bad at multitasking, Gazzaley says, because they have trouble redirecting attention back to a task after it has been interrupted. On average, people in their seventies generally require twice as much time to do two things at once as do young adults, and they also make more errors on the tasks. That inability to focus takes its toll. "I would not be capable of doing groundbreaking work today," renowned physicist Freeman Dyson, 88, told me recently. When he was young, Dyson said, he could focus on a single problem nonstop for a week. "Today," he said, "I'm limited to two hours a day of serious work—which wouldn't be enough."

THE DETERIORATION OF THESE FOUR SYSTEMS appears to be an inevitable part of normal, healthy aging, although the rate of decline varies among individuals (see "The Good News," page 50). When you add disease to the picture, things truly look bleak. Half of Americans over 85 are suffering from Alzheimer's disease, which eventually robs people of their memories, identities, and the ability to function even minimally. Alzheimer's becomes increasingly common with age—so common that neurologist Gary Small of UCLA suggests that if we all lived to 110, we all would have it. These are the brutal truths we must face as we and our loved ones age.

Robert Epstein is a research psychologist, a contributing editor for *Scientific American Mind*, and former editor-in-chief of *Psychology Today*.