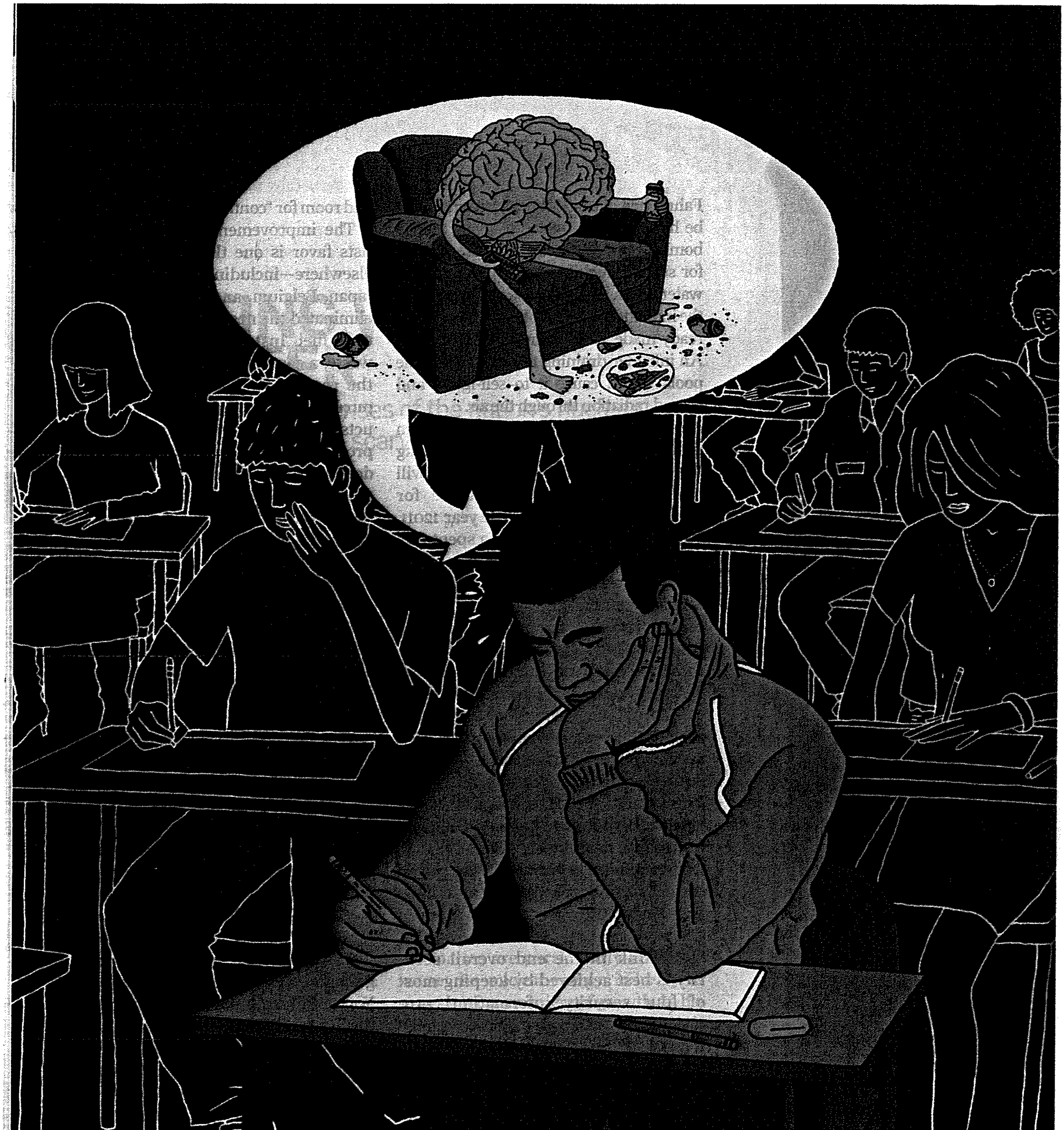

Can You Build

Blueberries and crossword puzzles aren't going to do it. But as neuroscientists discov

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a Better Brain?

he mechanisms of intelligence, they are identifying what really works. **By Sharon Begley**

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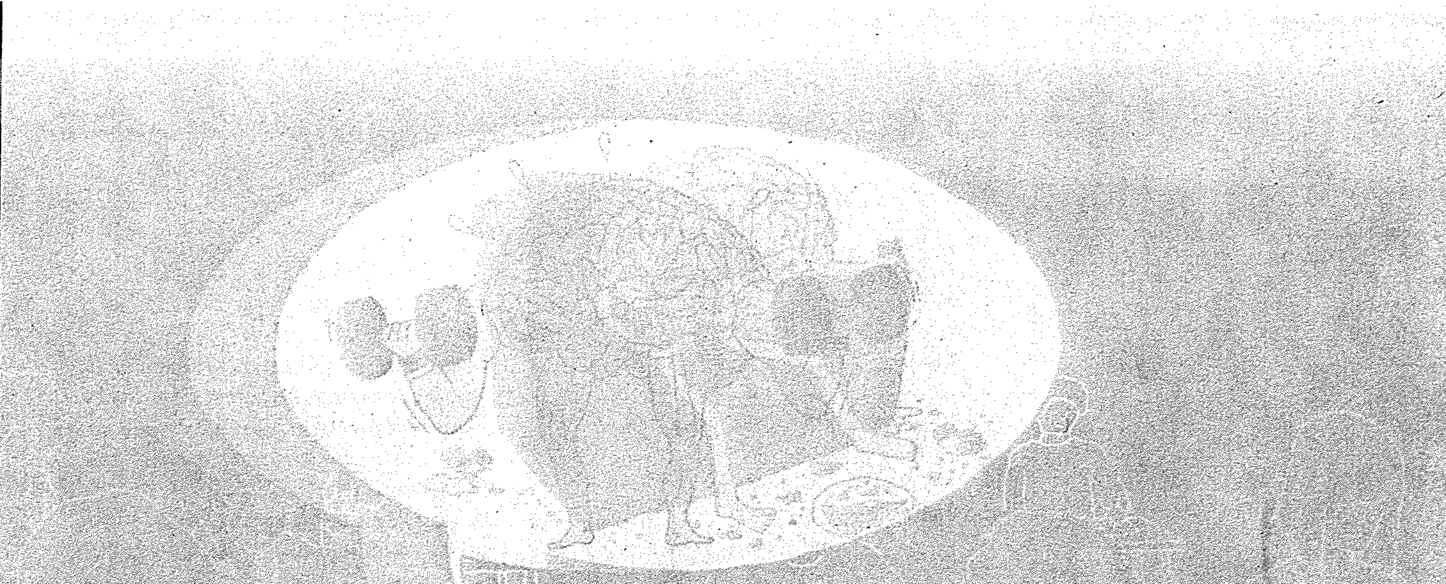


This would be a whole lot easier—this quest for ways to improve our brain—if scientists understood the mechanisms of intelligence even half as well as they do the mechanisms of, say, muscular strength. If we had the neuronal version of how lifting weights increases strength (chemical and electrical signals increase the number of filament bundles inside muscle cells), we'd be good to go. For starters, we could dismiss claims for the brain versions of eight-second abs—claims that if we use this brain-training website or practice that form of meditation or eat blueberries or chew gum or have lots of friends, we will be smarter and more creative, able to figure out whether to do a Roth conversion, remember who gave us that fruitcake (the better to retaliate next year), and actually understand the NFL's wild-card tiebreaker system.

But what neuroscientists don't know about the mechanisms of cognition—about what is physically different between a dumb brain and a smart one and how to make the first more like the second—could fill volumes. Actually, it does. Whether you go neuro-slumming (Googling "brain training") or keep to the high road (searching PubMed, the database of biomedical journals, for "cognitive enhancement"), you will find no dearth of advice. But it is rife with problems. Many of the suggestions come from observational studies, which take people who do X and ask, are they smarter (by some measure) than people who do not do X? Just because the answer is yes doesn't mean X makes you smart. People who use their gym locker tend to be fitter than those who don't, but it is not using a gym locker that raises your aerobic capacity. Knowing the mechanisms of exercise physiology averts that error. *Not* knowing the mechanism of cognitive enhancement makes us sitting ducks for dubious claims, since few studies claiming that X makes people smarter invoke any plausible mechanism by which that might happen. "There are lots of quick and dirty studies of cognitive enhancement that make the news, but the number of rigorous, well-designed studies that will stand the test of time is much smaller," says neuroscientist Peter Snyder of Brown University Medical School. "We're sort of in the Wild West."

A 2010 evaluation of purported ways to maintain or improve cognitive function, conducted for the National Institutes of Health, shows how many of the claims for cognitive enhancers are as sketchy as a Wild West poker player with a fifth ace up his sleeve. Vitamins B_6, B_{12}, and E; beta carotene; folic acid; and the trendy antioxidants called flavenoids are all busts, and the evidence for alcohol, omega-3s (the fatty acids in fish), or having a large social network is weak. The Mediterranean diet is associated with a lower risk of cognitive decline, find observational studies, but that hasn't been confirmed in more rigorous, randomized controlled studies, and no one knows whether the benefit comes from what the diet includes (olive oil, fish, vegetables, wine) or what it excludes (red meat, refined sugars, dairy fat). Statins don't help, and neither do estrogen or NSAIDs (aspirin, ibuprofen). Be skeptical of practices that promise to make you smarter by increasing blood flow to the brain—there is no evidence that's the limiting factor in normal people. Yes, you can find individual studies concluding that one or another hype-heavy intervention helps your brain, but the conclusion of any single study is more likely to be wrong than right. (For one thing, scientists and journals prefer positive findings and bury negative studies.) Only by assessing all the evidence from all the studies, as the NIH evaluation did, can you get the true picture.

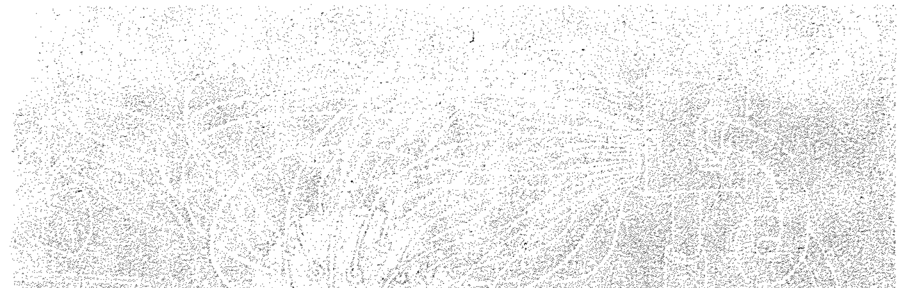
The quest for effective ways to boost cognitive capacity is not hopeless, however. The explosion in neuroscience is slowly revealing the mechanisms of cognition. "We have accumulated enough knowledge about the mechanisms and molecular underpinnings of cognition

at the synaptic and circuit levels to say something about which processes contribute," says James Bibb of the University of Texas Southwestern Medical Center, who organized a symposium on "cognitive enhancement strategies" at the 2010 meeting of the Society for Neuroscience. Greater cognitive capacity comes from having more neurons or synapses, higher levels of neurogenesis (the creation of new neurons, especially in the memory-forming hippocampus), and increased production of compounds such as BDNF (brain-derived neurotrophic factor), which stimulates the production of neurons and synapses, says neuroscientist Yaakov Stern of Columbia University. Both neurogenesis and synapse formation boost learning, memory, reasoning, and creativity. And in people who excel at particular tasks, Stern's neuroimaging studies show, brain circuits tend to be more efficient (using less energy even as cognitive demand increases), higher capacity, and more flexible.

One of the strongest findings in neuroplasticity, the science of how the brain changes its structure and function in response to input, is that attention is almost magical in its ability to physically alter the brain and enlarge functional circuits. In a classic experiment, scientists found that when monkeys repeatedly practiced fine-tactile perception, the relevant brain region expanded, just as it does when people learn Braille or the violin. Similarly, a region of the auditory cortex expands when we hear a particular tone over and over. (Yes, the spot that processes your ringtone is encroaching on next-door areas.) But when monkeys simultaneously touched something and listened to tones, only the brain region controlling the input they were trained to focus on expanded. In other words, identical input—tactile sensations and sounds—produces a different result, expanding a brain area or not, depending only on whether attention is being paid.

That might explain why skills we're already good at don't make us much smarter: we don't pay much attention to them. In contrast, taking up a new, cognitively demanding activity—ballroom dancing, a foreign language—is more likely to boost processing speed, strengthen synapses, and expand or create functional networks.

By nailing down the underpinnings of cognition, neuroscientists can separate plausible brain boosters from dubious ones. With apologies to the political-correctness police, nicotine enhances attention—that key driver of neuroplasticity—and cognitive performance in both smokers and nonsmokers, scientists at the National Institute on Drug Abuse reported in a 2010 analysis of 41 double-blind, placebo-controlled studies. Nicotine, they found, has "significant positive effects" on fine motor skills, the accuracy of short-term memory, some forms of attention, and working memory, among other basic cognitive skills. The improvements "likely represent true performance enhancement" and "beneficial cognitive effects." The reason is that nicotine binds to the brain receptors for the neurotransmitter acetylcholine that are central players in cortical circuits. (Caveat: smoking also increases your risk of dementia, so while cigarettes may boost your memory and attention



now, you could pay for it later. To be determined: whether a nicotine patch delivers the benefits without the risks.

Neuroscience supports the cognitive benefits of stimulants like Adderall and Ritalin, too, at least in some people for some tasks. Both drugs (as well as caffeine) raise the brain levels of dopamine, the juice that produces motivation and the feeling of reward. On balance, finds psychologist Martha Farah of the University of Pennsylvania, studies show that both drugs enhance the recall of memorized words as well as working memory (the brain's scratchpad, which plays a key role in fluid intelligence). They do not improve verbal fluency, reasoning, or abstract thought, however, nor provide much benefit to people with a gene variant that keeps dopamine activity high, Farah found in a recent study.

These limitations suggest two things. First, if you're naturally awash in dopamine and are highly motivated to, say, deduce from its source code how a website was built, then increasing dopamine levels pharmacologically is unlikely to help. Farah found no difference between the performance of volunteers given Adderall and volunteers given a placebo on a battery of cognitive tasks, suggesting that you can get the same dopamine-boosting benefits of the drug by simply believing that you'll do well, which itself releases dopamine. Second, the divide between the mental functions that drugs do and don't improve suggests that psychological factors such as motivation and reward help with memory, but not higher-order processes such as abstract thought. The drugs "will help some people some of the time, but maybe not by a whole lot," she concludes. Fun fact for anyone hoping for IQ in a pill: a recent survey of doctors finds they're more comfortable prescribing sex drugs than smart drugs.

Knowing that Adderall and Ritalin work, when they do, by giving you motivation and a sense of reward from, say, solving a Sudoku puzzle implies that other ways to achieve those feelings will also boost mental performance. That's probably the mechanism by which a whole slew of tricks work. Take, for instance, the "ancestor effect." As a paper to be published in the *European Journal of Social Psychology* reports, "thinking about our genetic origin"—how Grandpa survived the Depression, how Great-Grandma eluded the Cossacks, et al.—"enhances intellectual performance." The mechanism responsible for that is an increase in confidence and motivation—Adderall without the prescription. Along the same lines, a positive mood—even the kind that comes from watching "Sneezing Panda" on YouTube—can enhance creative problem-solving, finds a new paper in *Psychological Science*. In this case, reducing stress and the resulting cortisol, which attacks the myelin sheath that coats neurons and thus impairs signal transmission, allows underlying abilities to reach their full potential. Finally, being told that you belong to a group that does very well on a test tends to let you do better than if you're told you belong to a group that does poorly; the latter floods you with cortisol, while the former gives you the wherewithal and dopamine surge to keep plugging away.

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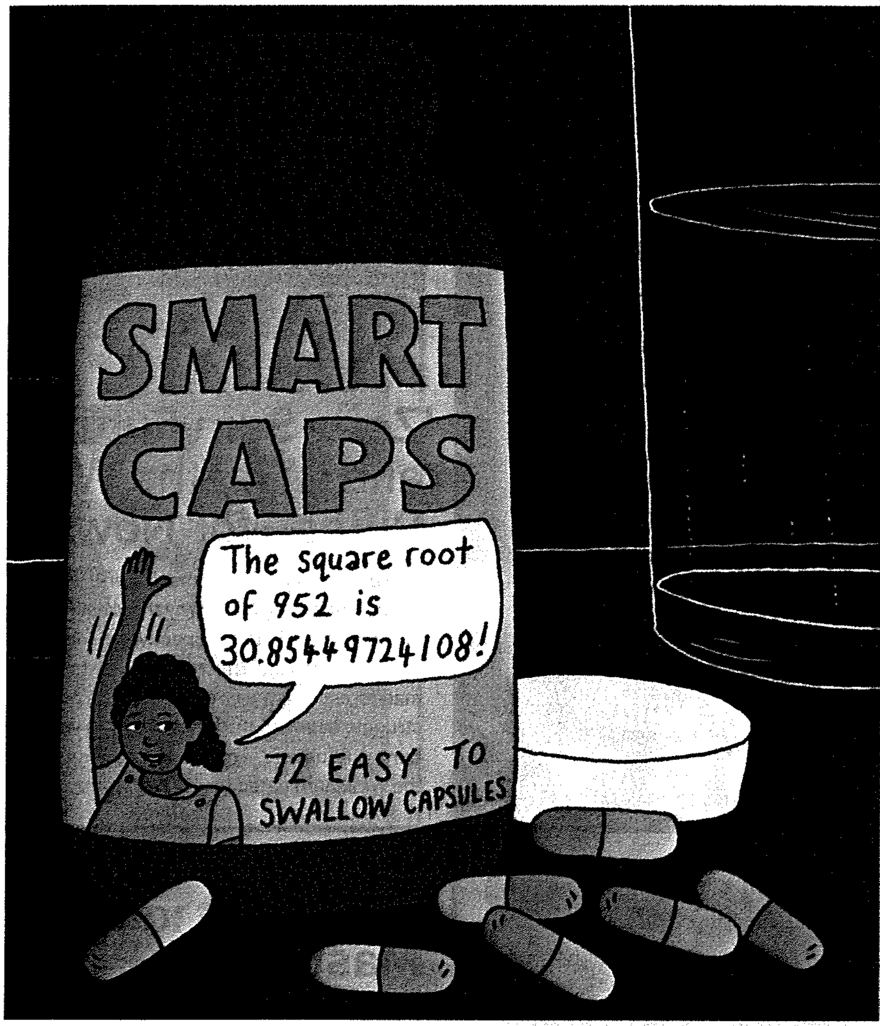
But there's a difference between reaching your natural potential by removing impediments such as stress and actually raising that potential. The latter requires tapping into one of the best-established phenomena in neuroscience—namely, that the more you use a circuit, the stronger it gets. As a result, a skill you focus and train on improves, and even commandeers more neuronal real estate, with corresponding improvements in performance. London cabdrivers who memorize that city's insanely confusing streets (25,000 of them) have a larger posterior hippocampus, the region that files spatial memories, than the average Londoner, neuroscientist Eleanor Maguire of University College London discovered in 2003. Conversely, if we offload our navigational ability onto GPS, we'll lose it.

The rule that "neurons that fire together, wire together" suggests that cognitive training should boost mental prowess. Studies are finding just that, but with a crucial caveat. Training your memory, reasoning, or speed of processing improves that skill, found a large government-sponsored study called Active. Unfortunately, there is no transfer: improving processing speed does not improve memory, and improving memory does not improve reasoning. Similarly, doing crossword puzzles will improve your ability to . . . do crosswords. "The research so far suggests that cognitive training benefits only the task used in training and does not generalize to other tasks," says Columbia's Stern.

The holy grail of brain training is



something that does transfer, and here there are three good candidates. The first is physical exercise. Simple aerobic exercise, such as walking 45 minutes a day three times a week, improves episodic memory and executive-control functions by about 20 percent, finds Art Kramer of the University of Illinois at Urbana-Champaign. His studies have mostly been done in older adults, so it's possible the results apply only to people whose brain physiology has begun to deteriorate—except that that happens starting in our 20s. Exercise gooses the creation of new neurons in the region of the hippocampus that files away experiences and new knowledge. It also stimulates the production of neuron fertilizers such as BDNF, as well as of the neurotransmitters that carry brain signals, and of gray matter in the prefrontal cortex. Exercise stimulates the production of new synapses, the connections that constitute functional circuits and whose capacity and efficiency underlie superior intelligence. Kramer finds that a year of exercise can give a 70-year-old the connectivity of a 30-year-old, improving memory, planning, dealing with ambiguity, and multitasking. "You can think of fitness training as changing the molecular and cellular building blocks that underlie many cognitive skills," he says. "It thus provides more generalizable benefits than specifically training memory or decision making."

The second form of overall mental training is meditation, which can increase the thickness of regions that control attention and process sensory signals from the outside world. In a program that neuroscientist Amishi Jha of the University of Miami calls mindfulness-based mind-fitness training, participants build concentration by focusing on one object, such as a particular body sensation. The training, she says, has shown success in enhancing mental agility and attention "by changing brain structure and function so that brain processes are more efficient," the quality associated with higher intelligence.

Finally, some videogames might improve general mental agility. Stern has trained older adults to play a complex computer-based action game called Space Fortress, which requires players to shoot missiles and destroy the fortress while protecting their spaceship against missiles and mines. "It requires motor control, visual search, working memory, long-term memory, and decision making," he says. It also requires that elixir of neuroplasticity: attention, specifically the ability to control and switch attention among different tasks. "People get better on tests of memory, motor speed, visual-spatial skills, and tasks requiring cognitive flexibility," says Stern. Kramer, too, finds that the strategy-heavy videogame Rise of Nations improves executive-control functions such as task switching, working memory, visual short-term memory, and reasoning in older adults.

Few games or training programs have been tested to this extent, and many of those that have been come up short. Those with increasing levels of difficulty and intense demands on attentional capacity—focus as well as switching—probably do the most good ... as does taking a brisk walk in between levels.

With IAN YARETT