

Fit Body, Fit Mind?

As everybody knows, if you do not work out, your muscles get flaccid. What most people don't realize, however, is that your brain also stays in better shape when you exercise. And not just challenging your noggin by, for example, learning a new language, doing difficult crosswords or taking on other intellectually stimulating tasks. As researchers are finding, *physical* exercise is critical to vigorous mental health, too.

By Christopher Hertzog, Arthur F. Kramer, Robert S. Wilson and Ulman Lindenberger

How can you stay sharp into old age?
It is not just a matter of winning the
genetic lottery. What you do can
make a difference



AT ONE TIME, THE ACCEPTED STEREOTYPE WAS THAT LEARN NEW TRICKS.” SCIENCE PROVED THIS DICTUM



Stimulating challenges such as puzzles help us keep our edge.

Surprised? Although the idea of exercising cognitive machinery by performing mentally demanding activities—popularly termed the “use it or lose it” hypothesis—is better known, a review of dozens of studies shows that maintaining a mental edge requires more than that. Other things you do—including participating in activities that make you think, getting regular exercise, staying socially engaged and even having a positive attitude—have a

meaningful influence on how effective your cognitive functioning will be in old age.

Further, the older brain is more plastic than is commonly known. At one time, the accepted stereotype was that “old dogs can’t learn new tricks.” Science has proved that this dictum must be discarded. Although older adults generally learn new pursuits more slowly than younger people do and cannot reach the peaks of expertise in a given field that they might have achieved if they had started in their youth, they nonetheless can improve their cognitive performance through effort—forestalling some of the declines in cognition that come with advancing age. As John Adams, one of the founding fathers and the second U.S. president, put it: “Old minds are like old horses; you must exercise them if you wish to keep them in working order.”

The news comes at a propitious time. The proportion of older adults in the U.S. and in other industrial nations continues to grow: in 1900, 4.1 percent of U.S. citizens were older than 65, but by 2000 that amount had jumped to 12.6 percent; by 2030, 20 percent of us will be in that category. From a societal point of view, prolonging independent functioning is both a desirable goal in itself and a way of deferring costs of long-term care. For individuals, maintaining optimal cognitive functioning

FAST FACTS

Aging and the Brain

1» We are used to thinking of intelligence as largely a matter of genetic inheritance, but that is not the whole picture. What you do affects your mental well-being: staying physically and mentally active helps us stay sharp as we age.

2» Nevertheless, our personal efforts to bolster cognitive enhancement cannot forestall all declines in our cognitive performance.

3» What is especially surprising is the powerful link between physical activity and mental acuity. Staying fit helps us keep cognition more robust as well.

“OLD DOGS CAN’T MUST BE DISCARDED.

is worthwhile simply because it promises to enhance quality of life through the years.

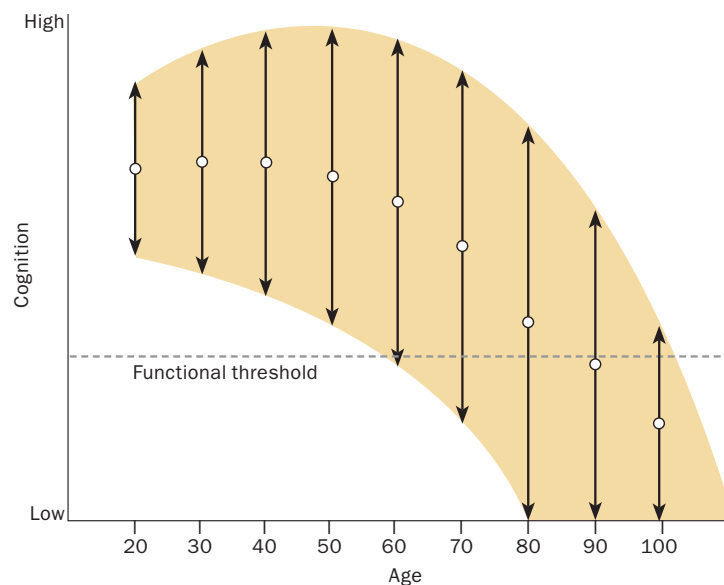
Mental Training

How to keep minds keen over an entire life span is a question philosophers have mulled since the earliest writings on record. As Roman orator Cicero put it: “It is exercise alone that supports the spirits, and keeps the mind in vigor.” Modern research in this field began in the 1970s and 1980s, with studies that demonstrated that healthy older adults can improve performance to a greater extent than had been previously assumed. The earlier research did not fully address certain questions, such as how long adults could retain the new skills they had acquired through training, whether those specifically developed skills would also positively influence other areas of cognition needed in everyday life, and whether the studies done with small numbers of subjects would be broadly applicable to most members of society.

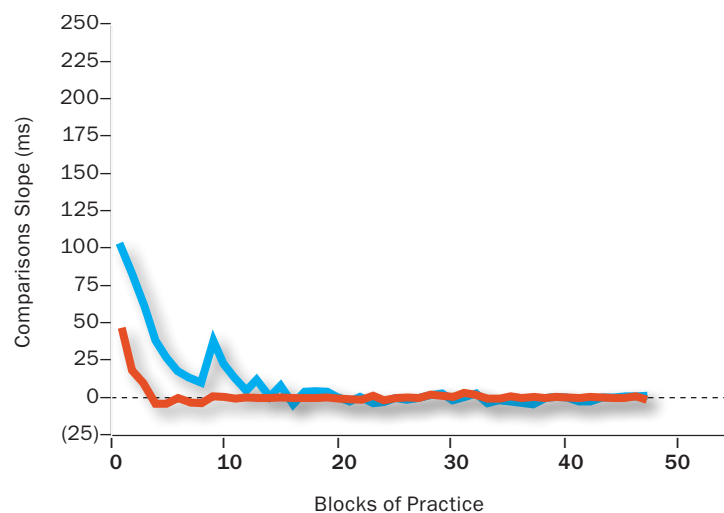
The latest experiments confirm that cognitive training does show substantial benefits for older adults and that these effects can be relatively long lasting. Around the turn of this past century the federal government’s National Institute on Aging funded a consortium of researchers to conduct a large-scale training study in a sample of older Americans. In 2002 psychologist Karlene Ball of the University of Alabama at Birmingham and her colleagues published initial results on more than 2,500 individuals older than 65 who had received about 10 sessions of cognitive training. Participants were randomly assigned either to a cognitive-process training group to learn how to excel in one of three areas—memory, reasoning or visual search—or to a control group of subjects who did not receive training. At a follow-up two years later, the team randomly selected a set of the initial participants to get booster training prior to evaluation. The results showed strong training-effect sizes in each group as compared with controls, along with a pattern of specificity in performance improvements. For example, individuals trained in visual search evinced strong gains in visual search performance but little improvement, relative to controls, on the memory and reasoning tests, a typical finding in training research. Data from retests five years later on the sample found that measurable training benefits were still present after the longer interval.

Capabilities over Time

An individual’s cognitive function can vary from maturity into old age. Although good habits can promote sound thinking within a given range (*top graph*), we cannot completely halt the effects of aging (*bottom graph*).



Cognitive function can change over a lifetime (*shaded area*). In addition to physical factors, environmental influences—such as engaging in mentally stimulating activities and exercising—can cause performance to boost or dip.



Older adults (mean age 72, *blue line*) were slower than younger adults (mean age 21, *red*) to search memory (comparison slope, *vertical axis*) to verify whether a word was one of a set they had committed to memory a short time earlier. But with enough practice, they could speedily identify target words without needing to search for them, producing zero slopes.

SCIENTIFIC AMERICAN MIND: SOURCE FOR TOP GRAPH: “ENRICHMENT EFFECTS ON ADULT COGNITIVE DEVELOPMENT: CAN THE FUNCTIONAL CAPACITY OF OLDER ADULTS BE PRESERVED AND ENHANCED?” BY C. HERZOG ET AL., IN *PSYCHOLOGICAL SCIENCE* (SUPPLEMENT TO *PSYCHOLOGICAL SCIENCE*) (IN PRESS); SOURCE FOR BOTTOM GRAPH: “AGING AND INDIVIDUAL DIFFERENCES IN THE DEVELOPMENT OF SKILLED MEMORY SEARCH PERFORMANCE,” BY C. HERZOG ET AL., IN *PSYCHOLOGY AND AGING*, VOL. 11, 1996

More impressive, however, are recent training studies that focus on what psychologists call executive function—how a person plans a strategic approach to a task, controls what is attended to, and how he or she manages the mind in the process. Unlike training that focuses on very specific skills, such as memorization strategies, training that aims to help people to control how they think appears to work on broader skills that are helpful in many situations that require thinking. For instance, psychologist Chandramallika Basak and her colleagues at the University of Illinois recently showed that training in a real-time strategy video game that demands planning and executive control not only improved game performance but enhanced performance on other tasks measuring aspects of executive control. Other results suggest that psychologists are learning how to train higher-level skills that may have a broader effect on cognitive function.

You don't have to have specialized training, however, to achieve cognitive gains or ward off cognitive decline. Everyday activities such as reading can help. We reviewed evidence on activity-related cognitive enrichment in more than a dozen studies.

In 2003 neuropsychologist Robert Wilson and his colleagues at Rush University Medical Center in Chicago recruited more than 4,000 elderly people from a geographically defined community and rated their frequency of participation in seven cognitive activities (for instance, reading magazines). At three-year intervals for a mean of nearly six years, participants completed an in-home interview that included brief tests of cognitive function. More frequent cognitive activity at the outset was associated with reduced rate of cognitive decline over time.

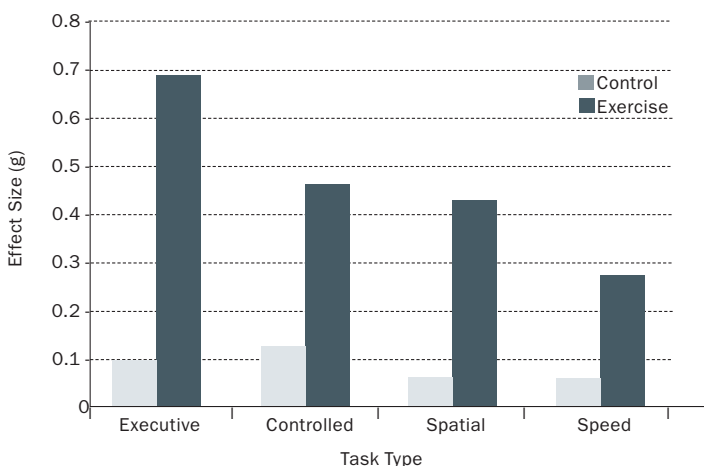
Getting Physical

Over the past decade several studies have underscored the link between physical activity and cognition. For instance, in a study published in 2001 neuropsychiatrist Kristine Yaffe of the University of California, San Francisco, and her colleagues recruited 5,925 women older than 65 at four different medical centers across the U.S. The participants were all free of any physical disability that would limit their ability to walk or pursue other physical activities. The volunteers were also screened to ensure that they did not have a cognitive impairment.

AFTER SIX TO EIGHT YEARS, THEY ASSESSED THE WORKING MEMORY FUNCTION. THE MOST ACTIVE HAD A 30 PERCENT

The Power of Pumping Iron

Older adults who participated in aerobic exercise (walking) outperformed those in programs for stretching and toning (controls) in cognitive task areas: executive (related to planning and multitasking), controlled (effortful processes in response to novel situations), spatial (dealing with spatial information in perception or memory) and speed.



The researchers then assessed their physical activity by asking the women how many city blocks they walked and how many flights of stairs they climbed daily and gave them a questionnaire to fill out about their levels of participation in 33 different physical activities. After six to eight years, they assessed the women's level of cognitive function. The most active women had a 30 percent lower risk of cognitive decline. Interestingly, walking distance was related to cognition, but walking speed was not. It seems that even moderate levels of physical activity can serve to limit declines in cognition in older adults.

Moderate movement is good, but toning your circulatory system with aerobic exercise may be the real key to brain fitness. In a 1995 study of 1,192 healthy 70- to 79-year-olds, cognitive neuroscientist Marilyn Albert of Johns Hopkins University and her colleagues measured cognition with a battery of tasks that took approximately 30 minutes to complete and included tests of language, verbal memory, nonverbal memory, conceptualization and visuospatial ability. They found that the best predictors of cognitive change over a two-year period included strenuous activity and peak pulmonary

SOURCE: "FITNESS EFFECTS ON THE COGNITIVE FUNCTION OF OLDER ADULTS: A META-ANALYTIC STUDY," BY STANLEY COLCOMBE AND ARTHUR F. KRAMER, IN *PSYCHOLOGICAL SCIENCE*, VOL. 14, NO. 2, MARCH 2003



MEN'S LEVEL OF COGNITIVE LOWER RISK OF DECLINE.

expiratory flow rate. In an investigation published in 2004 epidemiologist Jennifer Weuve of Harvard University and her colleagues also examined the relation between physical activity and cognitive change over a two-year period in 16,466 nurses older than 70. Participants logged how much time they spent per week in a variety of physical activities (running, jogging, walking, hiking, racket sports, swimming, bicycling, aerobic dance) over the past year and provided self-reports of walking pace in minutes per mile. Weuve's group observed a significant relation between energy expended in physical activities and cognition, across a large set of cognitive measures.

The research that we have described thus far has examined mental performance over relatively short periods—just several years. A few studies have begun to look at what happens over longer timescales. In 2003 psychiatrist Marcus Richards of University College London and his colleagues examined in a cohort of 1,919 men and women the influence of self-reported physical exercise and leisure-time activities at age 36 on memory at age 43 and on memory change from ages 43 to 53. Analyses indicated that engagement in physical exercise and other lei-

sure-time activities at 36 was associated with higher memory scores at 43. Physical activity at 36 was also associated with a slower rate of memory decline from 43 to 53 years of age after adjusting for spare-time activity and other variables. The data also suggested little memory protection for those who stopped exercising after 36 but protection for those individuals who began to exercise after this time.

In 2005 then graduate student Suvi Rovio of the Karolinska Institute in Sweden and her colleagues examined the relation between physical activity at middle age and risk of dementia an average of 21 years later, when the cohort was between 65 and 79 years of age. Subjects indicated how often they participated in leisure-time physical activities that lasted at least 20 to 30 minutes and caused breathlessness

Physical activity bolsters memory and thwarts dementia.

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Socializing—and even a positive attitude—helps your brain stay healthier.

and sweating. Conducting such activity at midlife at least twice a week was associated with a reduced risk of dementia in later life. Indeed, participants in the more active group had 52 percent lower odds of having dementia than the more sedentary group did.

Mind-Body Connection

It makes sense that training or participation in mentally stimulating activities would help cognition, but it is perhaps less immediately obvious why physical activity would have such an effect. Consider the increasingly well-documented link between physical activity and disease. A plethora of studies have examined the health benefits of exercise and a nonsedentary lifestyle for prevention of disease. For example, we now know that physical activity reduces the risk of cardiovascular-related death, type 2 diabetes, colon and breast cancer, and

osteoporosis. On the other hand, cardiovascular disease, diabetes and cancer have been associated with compromised cognition. Therefore, you might expect that increased physical activity and exercise would maintain cognition by reducing risk of diseases associated with cognitive decline.

In a study published in 2006 psychologist Stanley J. Colcombe of the University of Illinois and his colleagues examined the influence of fitness training on potential changes in brain structure. The six-month trial included 59 healthy but sedentary com-

POSITIVE ATTITUDES ENRICHMENT BECAUSE

munity-dwelling volunteers, age 60 to 79. Brain scans after fitness training showed that even relatively short exercise interventions can begin to restore some of the losses in brain volume associated with normal aging.

Supporting these findings, a large body of non-human animal research has demonstrated a number of changes in brain structure and function after animals are exposed to enriched, or complex, environments. Enriched environments usually include running wheels, a multitude of toys and objects to climb that are changed frequently, and animal companions. Exposure to such environments yields several physiological benefits. First, it increases the formation of new dendrite branches and synapses—the areas of neural cells that receive and send communication signals. It also increases the number of glial cells, which support the health of neurons, and expands the brain's oxygen-supplying capillary network. Enriched environments foster the development of new neurons and create a cascade of molecular and neurochemical changes, such as an increase in neurotrophins, molecules that protect and grow the brain.

Doing puzzles and push-ups are helpful for some—but other factors also boost mental fitness. For one, getting involved in social groups both improves cognition in general and seems to help thwart the arrival of dementia. The traditional focus of this research has been on relatively objective measures of social isolation versus connectedness, including the extent to which a person participates in activities that prominently involve social interaction (such as doing volunteer work), the number of friends and relatives an individual contacts regularly (in other words, the size of his or her social network), and marital status. Findings about the



More Science

See the *Psychological Science in the Public Interest* article, “Enrichment Effects on Adult Cognitive Development: Can the Functional Capacity of Older Adults Be Preserved and Enhanced?” on which this story is based, at the Association for Psychological Science's Web site: www.psychologicalscience.org

positive aspects of attitudes and beliefs on adult cognition are spottier. In large part, positive beliefs and attitudes may have important indirect effects on cognitive enrichment because of their influence on the kinds of behaviors (for instance, exercise and mentally stimulating activities) that are known to be associated with cognitive enrichment.

More generally, individuals who are optimistic, agreeable, open to new experiences, conscientious, positively motivated and goal-directed are more likely to undergo successful aging, to take

workplace) could help foster an enriching lifestyle.

At the same time, the public must be aware that there is still much that is not known about cognitive fitness in old age, as well as some controversy about the magnitude and durability of mental exercise outcomes. People are beginning to market computer games and other means of exercising the mind, often making strong claims about the effectiveness of expensive products that have not been backed by actual scientific studies. Consumers should look for evidence demonstrating the bene-

MAY HAVE IMPORTANT EFFECTS ON COGNITIVE OF THEIR INFLUENCE ON HEALTHY BEHAVIORS.

advantage of opportunities, to cope more effectively with life circumstances, to effectively regulate emotional reactions to events, and to maintain a sense of well-being and life satisfaction in the face of challenge.

And just as maintaining some activity patterns in old age may reduce risk of cognitive decline, the persistence of other patterns of behavior may actually increase the risk. Chronic psychological distress—resulting from depression, anxiety and negative emotions such as anger and shame—is associated with a variety of negative outcomes in adulthood, including cognitive decline. The tendency to experience psychological distress is often called neuroticism. Studies have consistently found a higher level of neuroticism to be linked to an increased incidence of Alzheimer's disease and mild cognitive impairment in old age.

Enriching Cognition

Clearly, there is no magic pill or one-shot vaccine that inoculates the individual against cognitive decline in old age. Thus, public policy regarding cognitive enrichment should follow a health prevention model. Policy leaders might promote intellectual activities that are inherently meaningful for older adults, perhaps as embedded in larger social contexts (for example, the Elderhostel movement or adult continuing education). A critical issue for future research will be to understand how an engaged way of life can be promoted and implemented in midlife, during the working years. Given inevitable conflicts between work demands and time available for other roles (parenting, for one) and activities, it would be useful to know whether work-related activity programs (such as availability and use of physical exercise facilities at or near the

fits of any such products, which may not necessarily incorporate all the features needed to enhance mental fitness in old age.

The next decades offer much promise for expanding our knowledge about aging and cognition. We may soon discover whether the limits on successful cognitive functioning in old age that were once seen as insurmountable can ultimately be viewed as pessimistic assumptions that focused on observable age-related decline rather than the potential for maximizing human performance through cognitive enrichment. Just as advances in medical science may lead to increased longevity through vehicles such as effective treatments for dementia-causing illnesses, advances in psychological science can make important contributions to improving the quality of life of long-living older adults, in part by empirically demonstrating that attitudes and behaviors can promote cognitive functioning in old age and, more generally, by showing how behavioral interventions can help us all age successfully. **M**

(Further Reading)

- ◆ **Capitalizing on Cortical Plasticity: Influence of Physical Activity on Cognition and Brain Function.** A. F. Kramer and K. I. Erickson in *Trends in Cognitive Sciences*, Vol. 11, pages 342–348; 2007.
- ◆ **Conscientiousness and the Incidence of Alzheimer's Disease and Mild Cognitive Impairment.** R. S. Wilson, J. A. Schneider, S. E. Arnold, J. L. Bienias and D. A. Bennett in *Archives of General Psychiatry*, Vol. 64, pages 1204–1212; 2007.
- ◆ **Relation of Cognitive Activity to Risk of Developing Alzheimer's Disease.** R. S. Wilson, P. A. Scherr, J. A. Schneider, Y. Tang and D. A. Bennett in *Neurology*, Vol. 69, pages 1911–1920; 2007.
- ◆ **The Neurogenic Reserve Hypothesis: What Is Adult Hippocampal Neurogenesis Good For?** G. Kempermann in *Trends in Neuroscience*, Vol. 31, pages 163–169; 2008.
- ◆ **Working Memory Plasticity in Old Age: Practice Gain, Transfer, and Maintenance.** S.-C. Li, F. Schmiedek, O. Huxhold, C. Röcke, J. Smith and U. Lindenberger in *Psychology and Aging*, Vol. 23, pages 731–742; 2008.