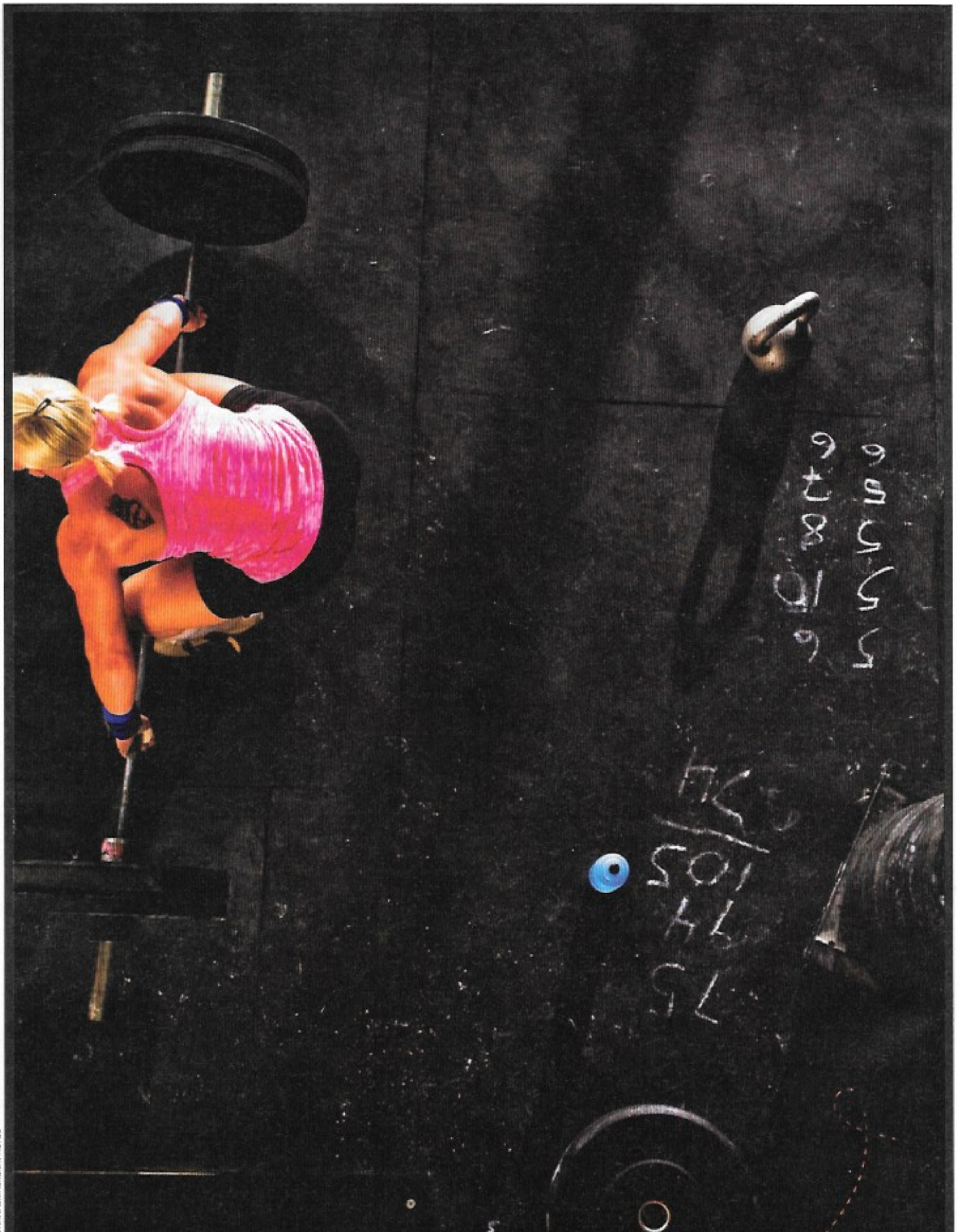


ROB HAMMER/AURORA PHOTOS

Circuit train your brain

Whether you need to focus better, improve your memory or curb unwanted cravings, specific exercise regimes can fine-tune your mind. **Teal Burrell** reports

PUMPING iron to sculpt your biceps. Yoga poses to stretch and relax. Running to whittle your waistline and get fit fast. There are loads of reasons why it's smart to exercise, and most of us are familiar with the menu of options and how each can shape and benefit your body.

But we are discovering that there are numerous ways in which exercise makes you smart too. Many of its effects have been going unnoticed, but if you were to peer inside the heads of people who like to keep active, you'd see that different exercises strengthen, sculpt and shape the brain in myriad ways.

That the brains of exercisers look different to those of their more sedentary counterparts is, in itself, not new. We have been hearing for years that exercise is medicine for the mind, especially aerobic exercise. Physical fitness has been shown to help with the cognitive decline associated with dementia, Parkinson's disease and depression, and we know this is at least in part because getting your blood pumping brings more oxygen, growth factors, hormones and nutrients to your brain, leading it – like your muscles, lungs and heart – to grow stronger and more efficient.

But a new chapter is beginning in our understanding of the influence of physical exercise on cognition. Researchers are starting to find more specific effects related to different kinds of exercise.

They are looking beyond the standard recommendation of 30 minutes of moderate, aerobic exercise a day, for the sake of your brain. Are there benefits to going slower or faster? To lifting weights, or performing sun salutations? Whether you want a boost in focus for an exam, find it hard to relax or are keen to quit smoking, there's a prescription for you.

The first clue that exercise affects the brain came from rodent studies 15 years ago, which showed that allowing mice access to a running wheel led to a boost in neuron formation in their hippocampi, areas of the brain essential for memory. That's because exercise causes hippocampal neurons to pump out a protein called brain-derived neurotrophic factor (BDNF), which promotes the growth of new neurons. The mice showed improvements in memory that allowed them to navigate mazes better.

The findings were soon translated to humans. Older adults who did aerobic exercise three times a week for a year also grew larger hippocampi and performed better in memory tests. Those with the highest levels of BDNF in their blood had the biggest increases in this brain region.

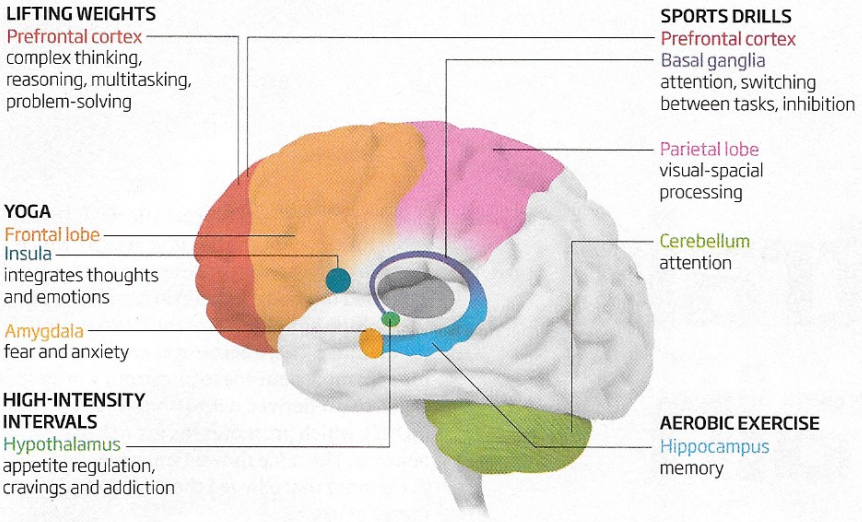
The idea that exercise helps to improve memory has been especially welcome given that the search for effective treatments for cognitive decline has been slow in progress. And it now seems that aerobic exercise such as running and cycling may help stave off Alzheimer's disease and other forms of dementia.

As the evidence for aerobic exercise accumulated, Teresa Liu-Ambrose at the University of British Columbia in Vancouver, Canada, began to wonder about other types of exercise. She has been looking for ways to halt dementia in people with mild cognitive impairment (MCI), a population of adults known to be at increased risk of developing dementia, and was especially interested in strength training, which has in recent years been added to US and UK government recommendations for physical activity.

To test the idea, Liu-Ambrose compared the effects of aerobic exercise and strength training in 86 women with MCI. She measured their impact on two abilities known to decline as the condition progresses: memory and executive function – which encompasses complex thought processes, including reasoning, planning, problem-solving and ›

The ultimate brain workout

Different physical exercises can bring specific mental gains, from improving memory to dealing with cravings or reducing stress



multitasking (see diagram, above).

Twice a week for an hour, one group lifted weights, while the other went for brisk walks quick enough that talking required effort. A control group just stretched for an hour instead. After six months of this, both walking and lifting weights had a positive effect on spatial memory – the ability to remember one's surroundings and sense of place.

On top of that, each exercise had unique benefits. The group that lifted weights saw significant improvements to executive function. They also performed better in tests of associative memory, which is used for things like linking someone's name to their face. The aerobic-exercise group saw improvements to verbal memory – the ability to remember that word you had on the tip of your tongue. Simply stretching had no effect on either memory or executive function.

If aerobic exercise and strength training have distinct benefits, is combining them the way to go? To address this, Willem Bossers of the University of Groningen in the Netherlands split 109 people with dementia into three groups. One group walked briskly four times a week for 30 minutes; a combination group walked twice a week and strength-trained twice a week for 30 minutes each; and a control group did no exercise. After nine weeks, Bossers put the participants through a battery of executive-function tests that measured problem-solving, inhibition and processing speed. He found that the combination group showed more improvement in executive function than the aerobic-only or control groups. "It seems that, for older adults, walking only is not enough. They need to do some strength training," he says.

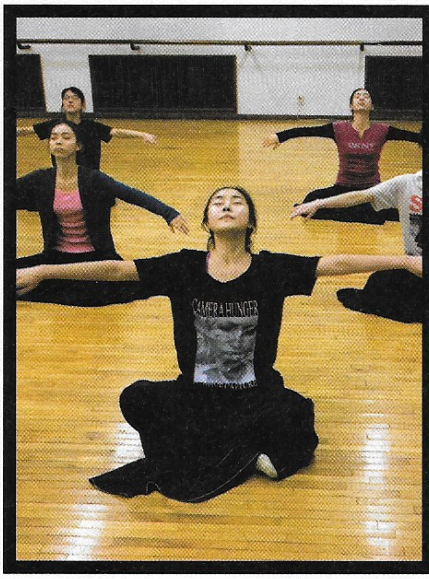
Immediate attention boost

And these benefits extend to healthy adults too. In a year-long trial of healthy older women, Liu-Ambrose found that lifting weights, even just once a week, resulted in significant improvements in tests of executive function. Balancing and toning exercises, on the other hand, did not.

The combination of lifting weights and aerobic exercise might be particularly powerful because strength training triggers the release of a molecule called insulin-like growth factor-1 (IGF-1), a growth hormone produced in the liver that is known to affect communication between brain cells, and to promote the growth of new neurons and blood vessels. On the other hand, aerobic exercise mainly boosts BDNF, says Liu-Ambrose. In addition, Bossers says strength training also decreases levels of homocysteine, an inflammatory molecule that is increased in the brains of older adults with dementia. By combining aerobic exercise with strength training, you're getting a more potent neurobiological cocktail. "You're attacking the system in two ways," he says.

The studies so far haven't addressed how long the effects last, but preliminary findings suggest adults will have to keep exercising to maintain the benefits.

Another approach is to start young, with findings that different types of exercise affect a child's mental capacity in a number of ways. For example, if you want kids to focus for an hour – on a maths test, say – the best bet is to let them have a quick run around first. That's according to studies that show a simple 20-minute walk has immediate effects on children's attention, executive function and



ELLIOTT ERWITT/MAGNUM PHOTOS

FEELING ANXIOUS? SAY "OM"

After a running injury, Sara Lazar decided to try yoga. She initially rolled her eyes when the instructor touted the mental-health benefits, but after a while she realised she felt better able to handle difficult situations. She decided to look into it at her lab at Massachusetts General Hospital, recruiting people who were experiencing high levels of stress to attend yoga and meditation classes for eight weeks. They also practised at home for 20 minutes a day. By the end, brain scans showed the volunteers' amygdalae - brain regions that process fear and anxiety - had shrunk, and participants reported feeling less stressed. While it's not yet clear why, yoga's meditative aspect helps develop a calmer outlook, which in turn reduces fear and anxiety, says Lazar.

"Lifting weights helps improve complex thoughts, problem-solving and multitasking"

BRUNO BARBEY/MAGNUM PHOTOS

Mind over matter: improving attention can help mobility. The stick is optional

achievement in mathematics and reading tests. Letting kids sprint or skip about has the same effect. A brisk walk can also help children with attention-deficit hyperactivity disorder to focus, although again it's not yet clear how long the effects last.

These findings should be used to make decisions about the daily school routine, says Charles Hillman at the University of Illinois at Urbana-Champaign, who carried out some of the research. He agrees with current recommendations that children get at least an hour of exercise daily, but notes that it might be best spread over the course of the day. Because purely aerobic exercise keeps kids focused in the near term, giving them breaks to walk or move around every 2 hours might be the best way to promote learning.

In contrast, exercise that is highly structured and focused on specific skills, such as for a sport or to improve coordination, hampers attention. A bunch of drills and rules may be too taxing for children right before a test or a situation that requires sustained focus.

Instead, these kinds of specific exercises seem to build up attention span gradually over the long-term. In research yet to be published, Maria Chiara Gallotta at the University of Rome in Italy found that twice-weekly sessions of coordinative exercises, such as basketball, volleyball or gymnastics practice, over the course of five months helped children do better on tests that required concentration and ignoring distractions.

The cerebellum – the finely wrinkled structure at the base of the brain – has been long known to be involved in coordinating movement, but is now recognised as having a role in attention as well. Practising complicated movements activates the cerebellum and, by working together with the frontal lobe, might improve attention in the process.

Making sure children are physically fit can have lasting cognitive benefits too, says Hillman. He has shown that children who are fit have larger hippocampi and basal ganglia, and that they perform better in attention tests. The basal ganglia are a group of structures important for movement and goal-directed behaviour – turning thoughts into actions. They interact with the prefrontal cortex to influence attention, inhibition and executive control, helping people to switch between two tasks, such as going from sorting cards by colour to sorting cards by suit.

Hillman focuses on children aged 8 to 11 because areas like the hippocampi and basal ganglia are still maturing, so intervening at ›

MIND GAMES FOR MOBILITY

Moving the body can tone the mind (see main story), but could the reverse also be true?

In other words, says Lindsay Nagamatsu at the University of Illinois at Urbana-Champaign, can a mental workout influence how the body moves?

It is commonly assumed that everyday movements like walking and maintaining posture are automatic. But even if we don't consciously think about them, they still require a level of attention.

This becomes more apparent as we age, and Nagamatsu's earlier work shows that older people whose minds tend to wander, or who score poorly on attention tests, are more likely to take a fall. Physiotherapy and exercise improve mobility, but Nagamatsu wondered if a boost in attention span could too.

To test this, she used a computer game that is known to improve attention and perception called Music Catch. She got people aged between 60 and 80 to either play this game for a total of 15 hours over five weeks, or another game known to help with working memory and reasoning but not attention.

Before and after this she tested their walking speeds, a commonly used indicator of someone's risk of falling or being able to live independently.

Nagamatsu showed that the Music Catch group ended up with significant improvements in speed. The game seemed to be particularly helpful because it required paying attention to multiple things at once, as we do when walking while carrying on a conversation, for example.

And walking speed might be important more generally: "It has also been shown to predict morbidity and mortality in older adults," says Nagamatsu, "so I think that it's an important outcome to try to improve."

a young age can make a big difference. And even small gains in fitness lead to measurable changes in the brain. In some of his studies, Hillman has put kids on year-long after-school fitness programmes. Many are overweight, and while they don't lose much weight, their brains do change. They're going from being unfit to slightly less unfit, says Hillman. "But we're still finding benefits to brain function and cognition."

Adults too can reap brain gains from sporty challenges, says Claudia Voelcker-Rehage at Chemnitz University of Technology in Germany. Her research on older adults showed an increase in basal ganglia volume following coordination exercises that included balancing, synchronising arm and leg movements, and manipulating props like ropes and balls, but not from aerobic exercise.

Surf yourself smart

So why the added benefits? Such activities require an understanding of where things are in space, so one explanation is that they activate both the visual system and the parietal lobe, the part of the brain that integrates sensory and spatial information.

Indeed, Voelcker-Rehage found that these types of exercise improved visual-spatial processing, required for mentally approximating distances – for instance, being able to assess whether you have time to cross the street before an oncoming car reaches you – more than aerobic exercise.

Another explanation comes from recent research by Tracy and Ross Alloway, both at the University of North Florida in Jacksonville. They found that just a couple of hours of activity of the type we often enjoy during childhood, such as climbing trees, crawling along a beam, or running barefoot, had a dramatic effect on working memory.

This is the ability to hold on to information and manipulate it in our minds at the same time. "It prioritises and processes information, allowing us to ignore what is irrelevant and work with what is important," says Tracy Alloway. "Working memory influences nearly everything that you do, from the classroom to the boardroom."

So what is it about climbing trees or beam balancing that is so beneficial? The researchers only found positive results when the activities were a combination of two things. They needed to challenge the sense of proprioception – the position and orientation of the body – and also needed at least one other element, such as navigation, calculation or locomotion. Basically, the advantages came from exercises in which we need to balance and think at the same time.

A good example is surfing, says Alloway. "In order to even catch a wave, you have to pay so much attention to proprioceptive information or you slip off your board; you also have to judge the best position to be in order to catch it, as well as to determine if another surfer has priority to catch a wave."

In their study, a group who did yoga, which involves proprioception, but not much mental reasoning, didn't see improvements in working memory; nor did a group merely learning new information in a lecture setting.

The results were the same for children and adults. "The adults in our study showed improved working memory after just a couple of hours of doing playground-type activities," Alloway says.

The more we learn about the effects of exercise on the brain, the more different types of benefits are emerging, extending beyond cognition to changes in behaviour.

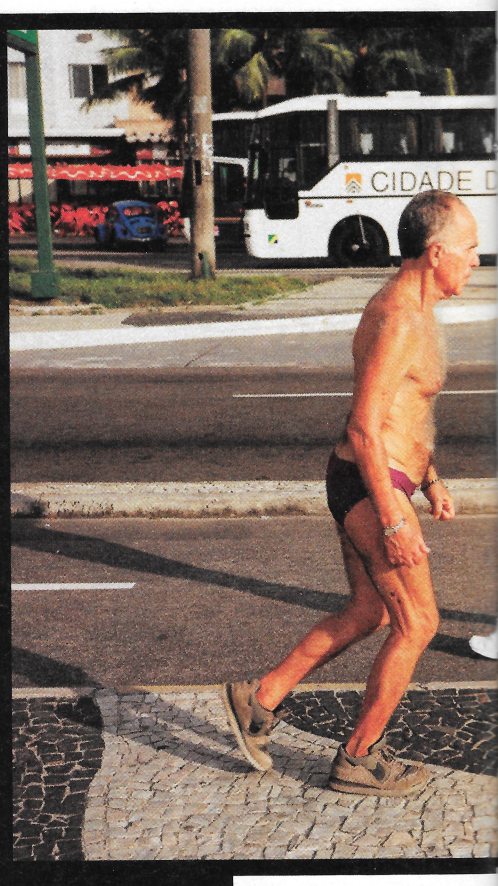
One of the most popular fitness trends of the last few years is high-intensity interval training, which involves quick spurts of all-out exercise. Its sheer toughness is claimed to

LET LOOSE FOR CREATIVITY

Daniel Schwartz practises what he preaches. During our interview he is strolling through Stanford University's leafy campus, an activity that according to his research boosts divergent creativity – otherwise known as thinking outside the box.

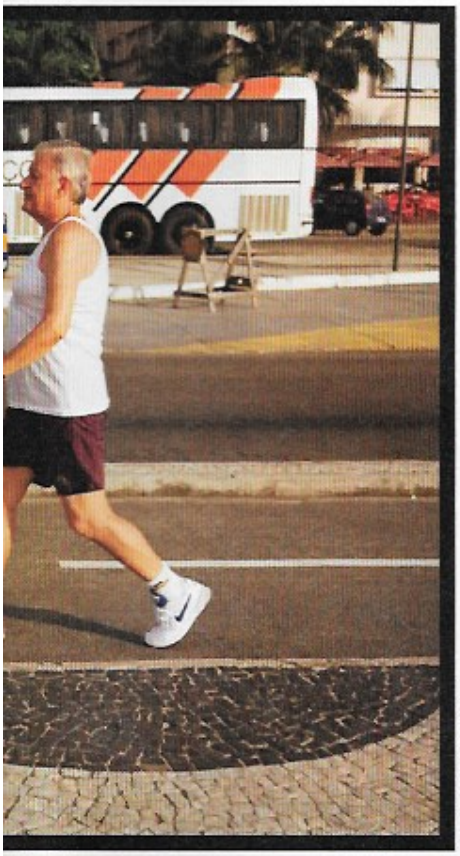
It is walking at a leisurely, everyday pace that does this, not at a speed that would be aerobically challenging or make you out of breath. In Schwartz's study – which he thought of while out on a walk – people came up with more unique uses for everyday objects when walking outside or on a treadmill than when seated. He even found that taking a walk has a stronger effect on creativity than IQ. And people continued to be more creative afterwards, suggesting a saunter before a brainstorming session is a good idea.

Or, if you're more of a jitterbug, Peter Lovatt, a dance psychologist at the University of Hertfordshire, UK, suggests you "put on some music and start having a boogie", and the key is to keep it loose. After a session when people had to improvise dance moves, they came up with more creative answers to problems than after a structured dance session or no dancing at all. It seems that creative movements – no matter how silly – lead to creative problem-solving. In fact, the sillier the better: the trick is to move in different ways. So if you tend to move your arms a lot when you dance, focus on your hips instead. "Having a spontaneous wiggle – without any pre-planning – is really good for divergent thinking," Lovatt says.



Taking a stroll can get the creative juices flowing

"Chocolate lovers consumed half as much after a brisk 15-minute walk. For smokers, 10 minutes of biking reduced cravings"



MARTIN PARR/MAGNUM PHOTOS

provide the same benefits as longer efforts in a fraction of the time.

These workouts might have an extra advantage: short bursts of activity can help curb cravings. And although the tougher the better, they don't necessarily have to be gut-bustingly hard.

To test the effects of intensity training on appetites, Kym Guelfi at the University of Western Australia in Perth invited overweight men to come into the lab on four separate occasions. On three of the visits, they spent 30 minutes on an exercise bike, but at different intensities – a moderate, continuous pace; alternating between intervals of high-intensity cycling for 1 minute followed by 4 minutes of moderate cycling; or alternating between very high intensity, 15-second sprints followed by one really easy minute. The fourth visit consisted of resting for the full 30 minutes.

Craving control

After the most intense intervals, the men ate less of the provided, post-workout porridge and less food overall for the next day and a half compared with days they cycled moderately or simply rested.

One explanation could be that the exercise reduced levels of the "hunger hormone", ghrelin. This is responsible for telling the part of the brain that controls eating – the hypothalamus – when the stomach is empty. When full, ghrelin production shuts off and hunger wanes. Following the most intense intervals of exercise, ghrelin levels were lowest.

If intensity isn't your thing, you could also play with the thermostat. Guelfi and others have shown that exercising in the heat reduces appetite, while exercising in the cold increases it. Again, hormones like ghrelin or a small protein called peptide YY could well be at play.

And although vigorous activity might curb appetite and stall cravings for longer, even moderate exercise can help. Adrian Taylor, now at Plymouth University in the UK, has found that short bouts of activity can reduce cravings for both sugary snacks and cigarettes.

In earlier work, Taylor found that chocolate lovers consumed almost half as much of it after a brisk 15-minute walk as those that rested quietly. For smokers, 10 minutes of moderate biking helped reduce self-reported cravings. Smokers' brains were also scanned while they viewed images designed to trigger cravings. Following cycling – despite staring at pictures of cigarettes after being deprived for 15 hours – the smokers' brains appeared relaxed. Regions implicated in addiction were less activated after exercise, as if the tempting cigarette were no more meaningful than a pencil.

It's conceivable that exercise merely distracts from the urge, but studies show that cravings were reduced more following a short bike ride than after another distracting task involving mental arithmetic.

It's still early days, and while some of the studies point at possible mechanisms behind the benefits, other effects have yet to be explored. One theory is that certain types of exercise increase blood-vessel formation in the brain, and so keep it working well. Exercises that activate specific regions may bring more blood to those areas, possibly building new vasculature that improves its functioning, whether it be for better memory or better problem-solving. And doing something unfamiliar, like learning a dance step or balancing on a beam, could also create novel connections between neurons, Voelcker-Rehage suggests.

What is clear is that these effects can endure well into old age, and it's never too late to start. The hippocampus shrinks as we get older, leading to the typical struggles with memory. But aerobic exercise not only prevents this loss – it reverses it, slowing the effects of getting older. Voelcker-Rehage has found that the brain requires less energy to complete certain tasks after exercise. "We would say that points to the fact that the brain is more efficient," she says. "It works more like a young brain."

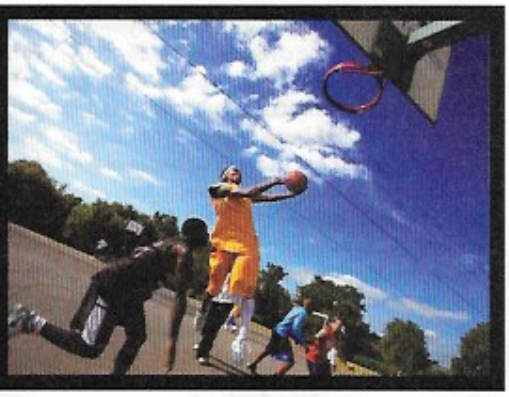
And in a study looking at yogis that had been practising for many years, Sara Lazar at Massachusetts General Hospital found that some brain regions were remarkably well preserved compared with those of healthy controls that were matched for age, gender, education and race. "The 50-year-old's brain looked like a 25-year-old's," notes Lazar.

If you're still unsure which type of exercise to pick, there's some overlap between the different exercises and benefits, so Liu-Ambrose's suggestion is simple: "If you're not active, do something that you enjoy." The best exercise is the kind that you'll actually do. ■

Teal Burrell is a science writer based in Washington DC. Links to studies appear in the online version of this article at bit.ly/NSbraintrain

EIGHT WAYS EXERCISE CAN BOOST YOUR BRAIN

IMPROVE WORKING MEMORY – surfing, running, climbing trees
BOOST CREATIVITY – dance or stroll
DE-STRESS – yoga
IMMEDIATE ATTENTION – unstructured play
LONG-TERM FOCUS – play sports
KEEP THE BRAIN YOUNG – running, yoga
CURB CRAVINGS – interval sprints
PROBLEM-SOLVING – lifting weights



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