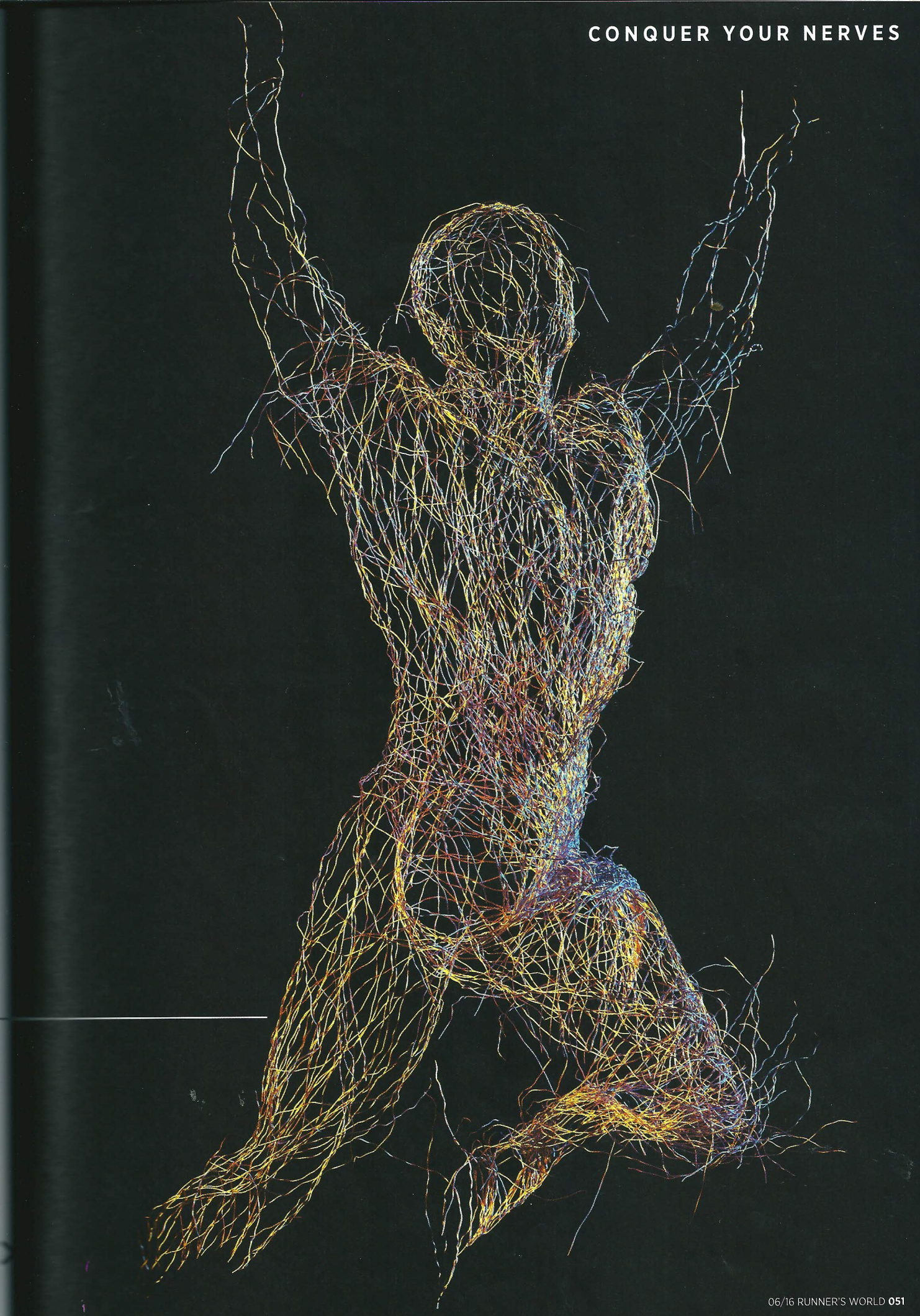
CIRCUIT TRAINING

A neurological master class in conditioning your nervous system for improved running performance

THE RIGHT PATH
Become wired for success

Any coach or training plan will readily extol the performance-boosting benefits of improving your cardiovascular system and strengthening your musculature. But while you may already be working hard on your VO_2 max and addressing your quad/hamstring imbalance, you probably haven't given a second thought to your neurological system. Which is a shame, because your network of nerves plays a key role in your running and, given the proper attention, can have a significant impact on your performance. 'People get intimidated when they hear the word 'neurological', but it's not as complicated as it sounds,' says Larissa True, assistant professor at the kinesiology department, State University of New York, and a keen runner. 'Think of it as the body's electrical wiring; the mechanism by which the brain communicates with the spinal cord and the limbs.'



In case you're still intimidated by talk of all things neurological, here's a brief introduction to your nervous system. It comprises two parts: the central nervous system (CNS) and the peripheral nervous system (PNS). The CNS is made up of the brain and spinal cord and is essentially the nervous system's command centre. 'The PNS is really everything else,' says True. 'The PNS branches off from the brain and spinal cord through the body and is charged with delivering information from the CNS and receiving signals from the environment.'

The PNS has two key departments: the sensory and motor divisions. The sensory division retrieves impulses from receptors in areas such as the skin, muscles and organs, and carries them through nerves to the CNS. The CNS then interprets those signals, and sends instructions via the motor division of the PNS to tell the appropriate muscle what to do in response.

The combined function of your CNS and PNS underpins every movement you make and also your ability to perceive and react to the environment. Once you grasp that, it's easy to see how your running potential is significantly influenced by the nervous system. And how well it performs its essential functions is down to signalling.

'The key cells in the nervous system are called neurons,' says biochemist Chris Cooper, author of *Run, Swim, Throw, Cheat: The Science behind drugs in sport* (OUP Oxford). 'The signal that activates them is electrical but this signal is transmitted by chemicals. An initial voltage charge triggers a release of a neurotransmitter molecule from the neuron. This neurotransmitter can then react with receptors on the surface of a nearby neuron. Multiple neurons make multiple connections with each other, so the pathways can become quite complex, and they result in muscle movement.'

The neuro zone

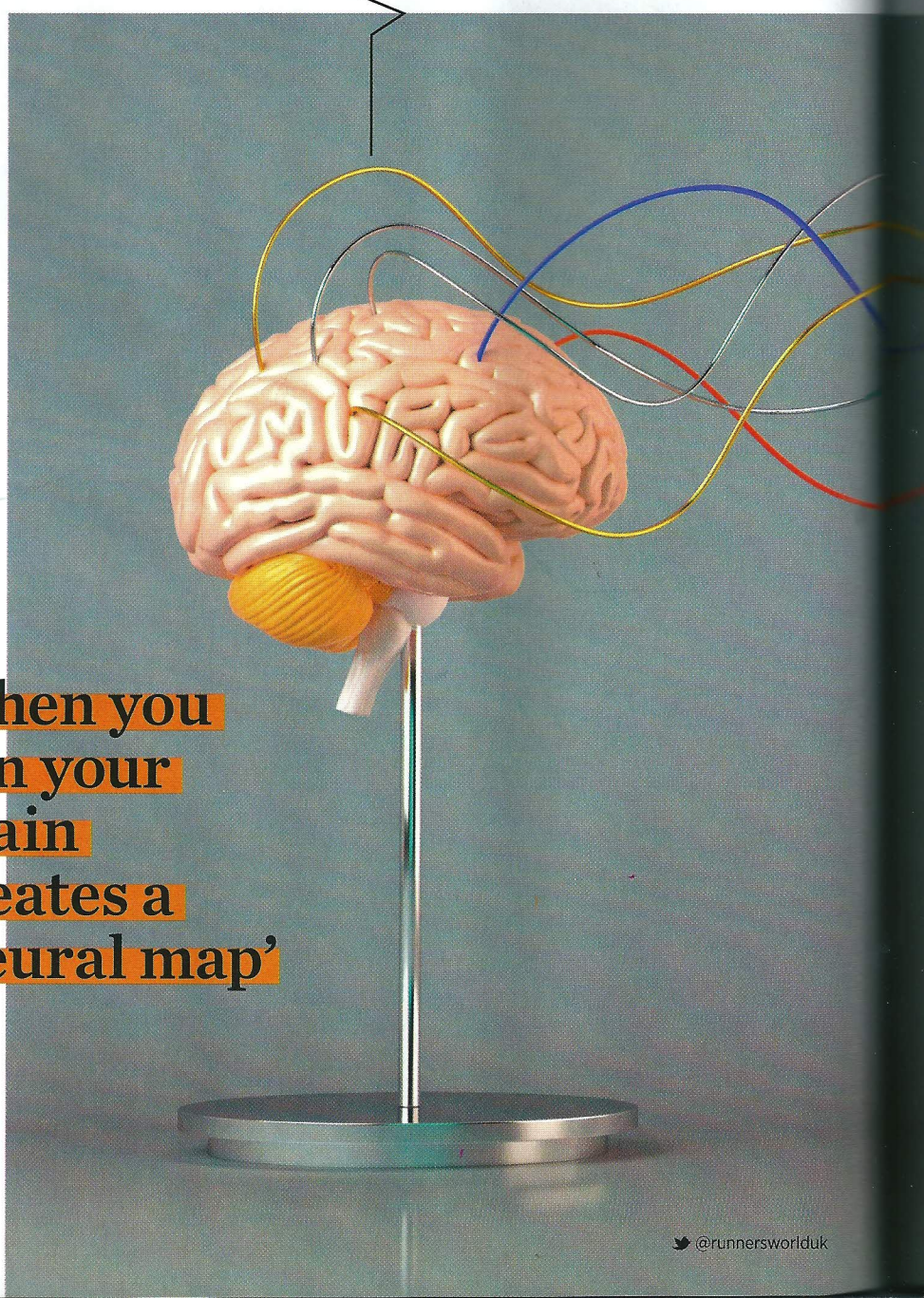
So, is there something different going on at a neurological level that propels elite runners? And if so, can we get a slice of that neurological action? When Finnish researchers studied the impact of sporting background on leg-muscle coordination they found the CNS influenced the firing and recruitment patterns of the participants' muscles, and they attributed these differences to the specifics of the sport and the effect years of training for that sport had on the CNS. They noted: 'Prolonged training in a specific sport will cause the CNS to programme muscle coordination according to the demands of the sport.'

That programming comes down to repetition, says Mike Antionades, coach and founder of The Running School in London (runningschool.co.uk). 'The more you run in a certain way,' he says, 'the greater the number of neurons that attach to the muscle, the stronger this connection becomes, the quicker this messaging goes to the brain, the more muscle gets recruited, the faster the movement.'

The type of running you do is worthy of consideration here. 'Long, slow runs don't stimulate the nervous system effectively,' says Antoniades. 'So even if you're in a base-building phase it's beneficial to schedule two speed sessions a week.' 'Repeat 10-12-second sprints at 90 per cent of your maximum. That short period is long enough to fire up the motor neurons, but not so long that you start creating lactic acid.'

And going up through the gears could have another beneficial effect on your neurons via a snappily titled substance called brain-derived neurotrophic factor (BDNF). 'BDNF is known to regenerate neurons throughout the neural system,' says True. It's thought to work by binding to receptors in the synapses to increase voltage and improve voltage strength. 'It's also important

BRAIN, MEET FOOT
They should get along very well



When you run your brain creates a 'neural map'

in motor learning; what's especially interesting is that its levels are activity-dependent. The more active you are, the more BDNF is secreted.'

Signal upgrades

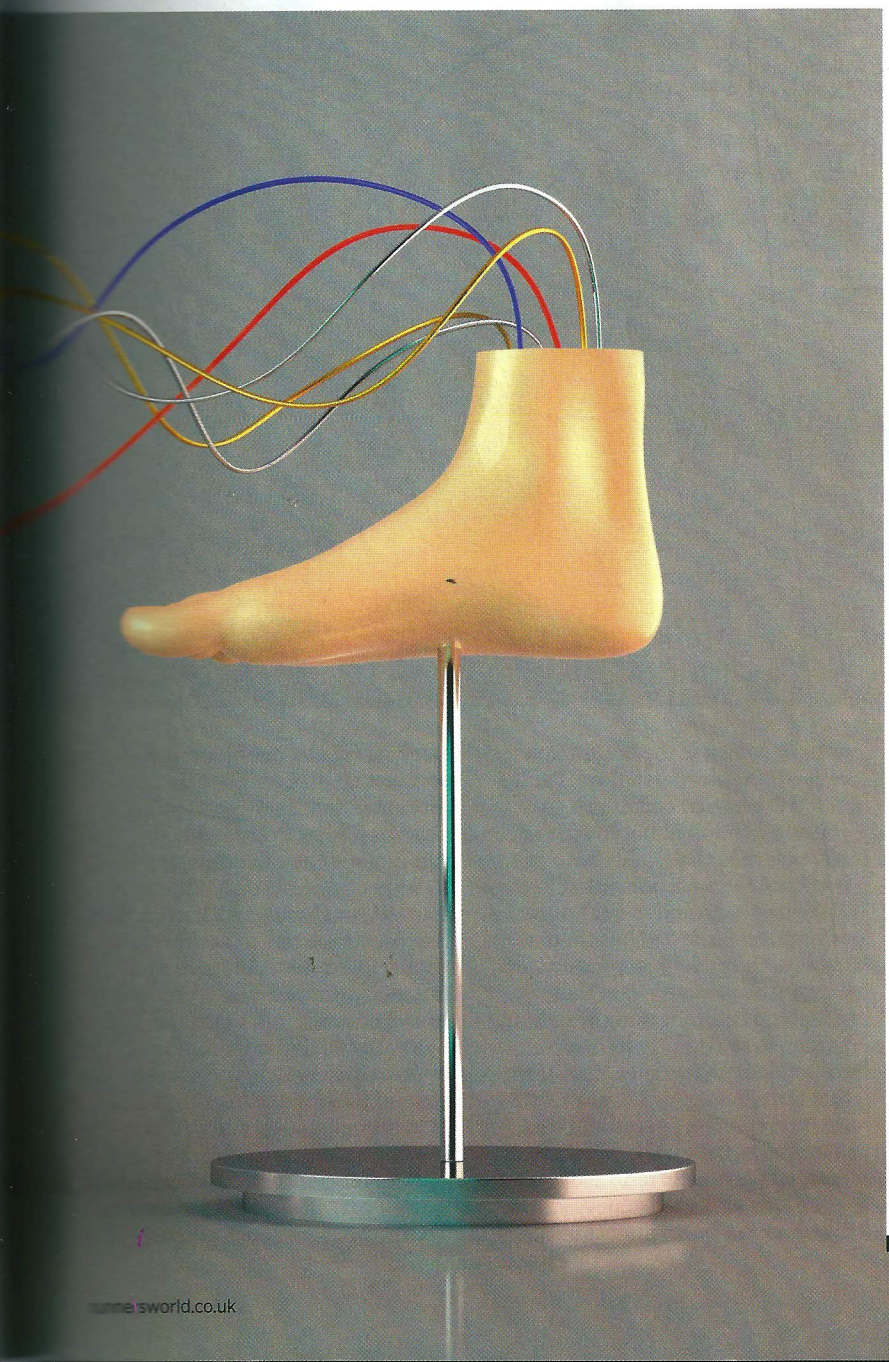
Neurons aren't the whole story, though. Also key to improving signalling and consequently your run performance is a pearlescent substance known as myelin. It's a sausage-skin like layer of dense fat that wraps around nerve fibres and works as insulation does on a wire, maintaining a strong electrical signal by stopping impulses leaking out. The thicker the myelin, the thicker the insulation, and the stronger the signal from one fibre to the next. And, again, you can improve the quality through practice.

'As you repeat any movement, the myelin becomes thicker,' explains Antionades. 'If you take violinists, myelin is a lot thinner on the hand holding the violin than the hand holding the bow because the bow hand is working through a more complex process and at greater speed. The same applies to running – faster runners will, in general, have a thicker covering of myelin over the nerve fibres involved in the running movement.'

Myelin arrives in a series of waves – some influenced by nature (DNA) and some by nurture (activity) – that last into young adulthood. To a lesser degree, adults retain the ability to produce myelin as they age, though it's best if this myelination, as it's called, derives from repetition of good technique (see *Neurological drills* below).

That question of technique is key to why your hundreds of hours repeating a running movement may not deliver the same results as say, David Rudisha's. 'The problem is we don't always fire the sequences – and hence recruit muscles – that elicit perfect form,' says Antionades.

When you run your brain creates a 'neural map' that, through repetition, will dictate your 'natural gait', but as Antionades has been preaching at The Running School for years, you



Neurological drills

Coach Mike Antionades on rebooting your neural pathways

01 FORM FOCUS

'The four running images show how the leg cycles up, activating the combination of muscles involved in good run technique,' says Antoniades. 'This is what drives motor reorganisation over a period of time.'

When running, try to cycle up from the back of the legs. Lead with the heel and try to bring it up above the height of the knee joint. This produces a cycle motion and reduces overstriding. Practise in short bursts of 20-30m, then relax.

02 GLUTE/ HAMSTRING ACTIVATOR

Why? 'This improves glute and hamstring activation. The gait of many runners is focused too much on the quads and hip flexors, causing tight IT bands. Keep your knee soft, not straight, and you bend from the hip, not the lower back. This produces a movement combination or muscle co-contraction of the glute and then the hamstring.

How? Take a small step forward with your left leg, keeping the knee slightly bent. Bend from the hip and extend the opposite hand forward. You'll feel the hamstring and glute activating as well as the lower-back muscles. Hold the stretch for two seconds and step back. Repeat 10 times on the same leg, then change sides. **Do five sets of 10 reps.**

Neural training

Three ways to boost your neural system

IMPROVE YOUR AWARENESS

Endurance coach Darren Smith recommends working on your proprioception. 'It's easily achieved,' says Smith. 'Simply stand on one leg while cleaning your teeth in the morning. It might feel odd but it improves your sense of awareness and will make your running more efficient.' You can increase the challenge to your neurological system and trigger more adaptation by doing this with your eyes closed, then progress to jumping and landing on one leg.

VISUALISE A NEW PB

'The best athletes engage in mental imagery,' says Ian Robertson, professor of psychology at Trinity College, Dublin. 'Athletes have been put through MRI scanners when undertaking this visualisation and those tests have shown that the majority of neural pathways that are active when you are doing the activity are also active when you're imagining it. So visualising your race unfolding positively can improve your performance on the big day.'

TRAIN YOUR CORE(TEX)

According to Marcora's model of fatigue, doing a boring mental task during a run taxes the brain's anterior cingulate cortex, which plays a key role in perception of effort. Do it in training, then remove that element before races and you'll lower your perceived effort. Download the Stroop Test app (free from iTunes) to your phone and place it in front of you on a treadmill. 'Doing a task like this, which involves saying the colour of a word rather than the word, activates this area of the brain more than exercising alone,' says Marcora

can reprogramme your network. 'It takes 40-60 days and a lot of repetition to change your neural map and for new technique to become an automated process,' he says. 'You should practise for at least 30 minutes a day for the first seven to 10 days and then three times a week to reinforce new pathways.' (See *Neurological drills*, p53)

Antionades also works with stroke patients and cites them to highlight the profound impact repetition has on the nervous system. 'If you have a stroke, part of the brain has died,' says Antionades. 'It has no link to the nervous system. But if you repeat a movement enough times with a stroke victim – and I mean thousands of times – the brain takes feedback from the bottom of the feet and starts to remap the neural system. This is called 'neural plasticity' and is truly remarkable.'

Nerve centre

Magnetic resonance imaging (MRI) is helping neuroscientists to paint a more detailed picture of what's going on in our neurological systems and brains as we move. Recent research by professor Martin Paulus at the University of California's OptiBrain Centre suggests a small structure deep in the brain gives some runners an advantage. Paulus found the insular cortex can give you an edge by making you more responsive to the signals from your body and the environment.

'We took elite and recreational adventure racers and had them breathe through an inspiratory tool,' explains Paulus. 'We gave them a visual cue before making breathing harder, to see how their brains responded to the signal. We found that the elite racers' insular cortex was more active. Essentially, they were preparing their brains before the challenge occurred.'

The insular cortex achieves this awareness of internal state and external cues by maintaining a neural map to organs and tissues throughout the body, and Paulus believes it's key to aspects of running such as correct pacing.

The good news is that, although some of your insular cortex function is defined by genetics, according to Paulus there are techniques that can mould your insular cortex and neural network into that of an elite. 'We've found that mindfulness training helps you to train these areas of the brain,' explains Paulus. 'It helps individuals and athletes become more aware of feelings and learn to temper their reactions to them. That's useful because studies have shown that non-resilient

GET THE MESSAGE
Neural training can boost speed

By training your healthy limb you subtly train the injured limb

people simply don't pay attention to their body's signals.'

The OptiBrain researchers discovered that mindfulness improves cognitive performance during stressful situations, leading you to make better decisions. 'That helps when deciding whether to have an energy drink, or increase or decrease pace,' says Paulus.

Mindfulness means achieving a mental state where you are entirely focused on the present moment. You may think this mind-body unity happens naturally on a run, but the chances are your mind will wander. To achieve mindfulness, try focusing on your breathing, its rhythm, sounds and the in/out motion of your muscles. Stay aware of what's around you but concentrate on how running feels; be aware of each muscle activated through the phases of the running motion and how it responds to the demands. Process this information without trying to interpret what it means to your run – the goal is simply to be aware of it.

Paulus's model ties in with the work of professor Samuele Marcora, director of research in the School of Exercise Sciences at the University of Kent, whose psychobiological model of fatigue gives a region of the brain called the anterior cingulate cortex a central role when you decide to speed up, slow down or give up. Marcora dismisses the traditional physiological model of fatigue, based around low glycogen levels or lactate-heavy blood. His model focuses on perception of fatigue and motivation.

'Things like glycogen do play a part, but an indirect one,' says Marcora. 'If your muscles are weaker, you have to increase central motor command to compensate. This is perceived as increased effort, which will ultimately slow you down.'

Marcora's model follows Tim Noakes' central governor model of fatigue. Though the two scientists seemingly enjoy Twitter warfare, Marcora extolling the virtues of his conscious theory over Noakes' subconscious model, both follow a similar idea of the brain interpreting and acting on neurological signals. Marcora shows you how to train your anterior cingulate cortex to boost your running in *Neural training*, above left.

Understanding the complex functionality, interconnection and adaptability of your brain and nervous system is also important when coming back from injury. When you return from a broken leg, for example, the limp lingers beyond the pain and the plaster because during your recovery period your brain has mapped out a new neural network for pain-free walking, which has become a habit.

Better news is that your injured leg won't have withered away as much as it could have owing to you exercising, somewhat counter-intuitively, your other leg. 'There's research that shows a phenomenon called bilateral transfer,' says True. 'This says that by training your healthy limb – and, in turn, the body's neurological pathways – you subtly train the injured limb.'

We're so interconnected that by exercising one part of our bodies, we're keeping the channels of communication open to the injured side. And it's not just limb for limb. Research published in the *European Journal of Applied Physiology* found that upper-body work can affect the lower body and vice versa. That's clearly significant when considering the importance and potential benefits of cross-training when you have an injury. It's not just the cardiovascular system and general fitness that will benefit – by exercising healthy limbs you'll help to reduce the de-training effects in your injured limbs and prime yourself for a speedier comeback.

Brain teaser

There's still much for scientists to learn about the impact of the brain and nervous system on running performance. However, as technology in tools such as MRI machines improves and becomes more readily available, researchers are unearthing an increasing amount of information that can translate into performance-boosting techniques. This includes advice that might support what you're already doing – like speedwork to stimulate the nervous system, but it's also opening up new and more extreme methods such as transcranial direct current stimulation. Employing this technique, which involves zapping the brain's insular cortex with a weak electrical current, Alexandre Okano of Brazil's Federal University of Rio Grande do Norte showed that a group of cyclists generated four per cent more power and reported lower perception of effort.

It's intriguing, but for now we suggest you stay well away from electrodes and concentrate on technique drills, speedwork and a little mindfulness to prime your pathways to fulfill your performance potential. RW