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AS YOUR eyes skip across the words on this page, it is likely that you are not only reading, but also thinking about yourself reading. Are the words clear? Can you concentrate? Do you have time to read this article now or are you feeling rushed?

Psychologists have a term for this kind of awareness of our own minds: metacognition – literally, the ability to think about our own thinking. Being able to turn our thoughts on ourselves is a defining feature of being human. But we often overlook the power it has in shaping our lives, both for good and ill. The importance of good self-awareness can seem less obvious than, say, the ability to make mathematical calculations or remember facts. Instead, for most of us, metacognition is like the conductor of an orchestra, occasionally intervening to nudge the players in the right (or wrong) direction.

Now, research from my lab and others is pulling back the veil on self-awareness, giving us a new-found respect for the power of the reflective mind. We have found ways to measure it, and can even watch it in action using brain scanning technology. What we have discovered is already suggesting a rethink in the way we understand brain disorders like dementia, but it has implications for us all. Boosting self-awareness can improve our decisions, open our eyes to fake news and help us think clearly under pressure. Just as a good conductor can make the difference between a routine rehearsal and a world-class performance, the subtle influence of metacognition can make the difference between failure and success in many aspects of life.

We rely on metacognition in all sorts of situations. For instance, when revising for an exam, you might reflect on how well you know the material, or whether you need to brush up on certain topics – metacognition about your memory. Or, on a visit to the opticians, you might be asked whether your vision is better or worse with a new pair of glasses – metacognition about your perception. More broadly, we can attempt to see ourselves through the eyes of others by taking a sort of third-person view of our personalities, skills and abilities.

Know your mind

The idea that self-awareness can be beneficial has a long history. Even before the ancient Greeks, thinkers have suggested that self-awareness is something to be striven for, and the essence of a life well-lived.

Even so, until relatively recently, metacognition wasn't considered a bona fide target of scientific inquiry. René Descartes relied on self-reflection to reach his famous conclusion "I think, therefore I am," noting along the way that "there is nothing that can be perceived by me more easily or more clearly than my own mind". This view left little room for the idea that self-awareness may be a brain process like any other, and equally prone to error or malfunction. Another French philosopher, Auguste Comte, thought the idea that self-reflection could be a mental process was nonsense, suggesting that it was simply impossible for a single brain to turn its thoughts upon itself. Self-awareness was therefore mysterious, indefinable and off limits to science.

We now know that the premise of Comte's worry is false. The human brain is no longer viewed as a single, indivisible organ. When we think about ourselves, particular brain

networks crackle into life, and damage or disease to these same networks can lead to devastating impairments of metacognition.

My lab at University College London focuses on understanding the mechanisms and neural basis of human metacognition. We are particularly interested in people's confidence in what they do and do not know. For example, in the middle of a pub quiz, you might ask your teammate whether they are sure they know the right answer (a confidence judgement about their memory). Or you may question whether a friend is certain it was really a celebrity they just spotted on a crowded high street (a confidence judgement about their perception). Having higher confidence when you are right and lower confidence when you are wrong leads to what psychologists refer to as having good metacognitive sensitivity – the extent to which our self-evaluations are sensitive to changes in our performance. This is subtly but importantly different from our general level of confidence, which is known as metacognitive bias. Many a pub quiz team has been hampered by someone with poor metacognitive sensitivity.

One way to measure these different facets of self-awareness in the laboratory is to use computer-based tests. In one task, we ask people to quickly decide which of two images contains a greater number of dots and then rate their confidence in this choice on a sliding scale. By observing someone's confidence on multiple occasions and recording whether their subsequent answers are right or wrong, we can build up a detailed statistical picture of someone's metacognition. This also allows us to summarise their metacognitive ability as a set of parameters – for instance, sensitivity and bias – known as their metacognitive fingerprint.

Psychologists have an increasingly detailed understanding of the brain circuits supporting this kind of self-knowledge too. The first hints that brain damage could lead to problems with metacognition came in the mid-1980s. Arthur Shimamura, then at the University of California, San Diego, was studying people who were left amnesic due to damage to the temporal lobes, regions known to be important for memory. What was surprising was that some of his patients were unaware of having memory problems. In laboratory tests, they showed a striking deficit in metacognition: they were unable to rate how confident they were in getting the answers right or wrong. It turned out that those individuals with metacognitive problems also had damage to the prefrontal cortex, part of brain involved in complex thought, decision-making and personality. More specifically, the damage affected the machinery that we now know is involved in building recursive models of ourselves and others.

This fits with what we know from animal models, which indicate that there are exquisitely sensitive representations of confidence in similar brain areas to those damaged in those patients with metacognitive difficulties. One study showed that neurons in the rodent orbitofrontal cortex, which sits right at the front of the brain, track confidence in decisions about different odours, measured by how long a rat was willing to wait for a reward after making a correct decision. It also demonstrated that inactivating these circuits of neurons impairs metacognition, while leaving the accuracy of odour decisions unaffected.

In another study, my colleagues and I found that subtle structural differences in the prefrontal cortex of otherwise healthy people could predict their metacognitive fingerprint. Since then, by using functional MRI technology to show brain activity in real time, my team has characterised how patterns of activation in different prefrontal subregions can predict how confident people feel in their decisions.

But aside from confidence, there is also a more elaborate aspect to metacognition, one that may be unique to humans and which allows us to consciously think about our own minds and the minds of others. This "explicit" form of self-awareness emerges between the ages of 3 and 4, continues to develop throughout adolescence and shares neural machinery with mentalising – our awareness of other people's mental states.

In fact, it now seems likely that the brain computations that elicit this explicit metacognition work as a "second-order" process that infers how confident we feel in our decisions or actions from a variety of cues, just as we infer what is happening in the minds of others from what they do or say. Because the brain circuity for explicit metacognition has a wide-angle lens, we have shown that it is able to pool information arising from different sources, tagging this information to create abstract estimates of our skills and abilities.

What this research is telling us is that the human brain plays host to specific algorithms for self-awareness. In turn, these findings imply that the effects of brain damage on self-awareness may be more widespread than we think. People with dementia may experience what clinicians refer to as anosognosia or loss of "insight" – being unaware of having cognitive problems. One way of understanding the causes of a loss of insight is that the disease has not only affected the brain circuits involved in memory and cognition, but also those responsible for maintaining normal self-awareness. If the capacity for metacognition becomes eroded, we may remain unaware of changes in our abilities and be unable to understand what we have lost. This lack of metacognition may lead people to be reluctant to seek help, or take steps – such as writing lists – to guard against memory failure. And while lack of insight is acutely understood by clinicians to be a key feature of early dementia, metacognition isn't yet part of standard neuropsychological assessment.

Better decisions

As the ancient Greeks also correctly believed, accurate metacognition is critical for success in a range of endeavours. If a student is aware of what they do and don't know, they will be able to make good decisions about what to study next. These decisions may seem minor, but they can end up being the difference between passing or failing an exam. Beyond the classroom, an accurate sense of confidence in our beliefs and decisions has been shown to increase people's ability to know when we might be wrong about issues ranging from politics to scientific theories, and provide the mental foundations for subsequent changes of mind. For instance, recent studies suggest that having an ability to engage in "cognitive reflection" – avoiding falling for an answer that initially feels right, but ends up being wrong – is an important component to resisting misinformation and fake news.

A final benefit of metacognition is that it helps us collaborate with others and that sharing information about confidence with teammates helps groups make better decisions. For instance, in laboratory experiments, pairs of people make more correct decisions when they are allowed to communicate their confidence in what they are seeing on a computer screen. However, this benefit critically depends on both individuals in the pair having good awareness of when they are likely to be right or wrong.

Our metacognitive fingerprint emerges in childhood (see box), but even in adulthood, metacognition isn't set in stone and can be affected by stress or differences in mental health. In one study from my lab, we asked hundreds of people to answer questions about different mental health symptoms. From the pattern of their answers, we could see where each person

fell on three core dimensions of mental health: their levels of anxiety and depression, their levels of compulsive behaviour and intrusive thoughts and their levels of social withdrawal. Where they sat along these dimensions predicted their metacognitive fingerprint. People who were more anxious and depressed had lower confidence but heightened metacognitive sensitivity, whereas those with compulsive behaviour and intrusive thoughts showed the reverse pattern.

A growing appreciation that metacognition relies on specific, malleable brain processes leads to a natural question: can we alter this neural circuitry to improve self-awareness? A deluge of self-help books and blogs encourage us to "find ourselves" and become more self-aware, but little attention is paid to how such change actually works, and rarely are the potential gains in metacognition assessed using objective tools. Questionnaire measures of self-awareness are less useful because, by definition, if you have poor metacognition, you are unlikely to be able to accurately report it. So the jury is still out on these self-help approaches. The tools of metacognitive neuroscience are a better bet, as they help us directly target the mechanisms of self-awareness. For instance, researchers at Trinity College Dublin, Ireland, have found that applying a kind of non-invasive brain stimulation called transcranial direct current stimulation to the prefrontal cortex can make older people more aware of their errors in simple tasks.

Drugs that increase levels of dopamine in the brain, and reduce levels of noradrenaline, have also been shown to benefit self-awareness, boosting metacognitive sensitivity without changing other aspects of performance.

In Japan, researchers at Advanced Telecommunications Research Institute International have developed "real time" brain scanning technology to train people to activate specific patterns of neural activity related to their levels of metacognitive confidence. After two days of this training, participants' metacognition was subtly altered, with people who were trained to boost "high confidence" brain patterns showing greater confidence in an unrelated task, and those trained to boost "low confidence" brain patterns showing the opposite change.

Brain stimulation and designer drugs are extreme ways of improving self-awareness. But more of us might be willing to invest time in training our metacognition. With this goal in mind, my lab has been working on tools to provide feedback on people's metacognitive judgements. We asked volunteers to spend around 20 minutes per day practising a simple perceptual discrimination, namely choosing which of two images was brighter. We found that those who were given feedback about their metacognition – whether their confidence judgements were accurate or inaccurate – had heightened metacognitive sensitivity after two weeks of training. Strikingly, these improvements in metacognition were also seen on a memory task that wasn't part of the training. In other words, having learned to boost metacognition on one task, people became more aware of whether they were right or wrong on a different one. This suggests that the training might be honing a more general system for self-awareness.

Another way of achieving similar effects may be through regular meditation. The impact of meditation on metacognition has only recently been explored. But initial results are encouraging. One study found that two weeks of meditation training could increase metacognitive sensitivity during a memory test. Other work has shown that expert mediators have greater metacognitive sensitivity compared with novices.

Perhaps the most useful way of improving self-awareness, though, is by recognising the situations in which it may become impaired. In a culture of efficiency and productivity, taking time to reflect on what we are doing seems to be an optional luxury. Paradoxically, we often most need self-awareness at precisely the times when it is likely to be compromised. As the pressure comes on at work or when we are stressed by money or family worries, engaging in effective metacognition might reap the most benefits, enabling us to recognise errors, or realise when we need to ask for help or change strategy. But laboratory studies have consistently shown a link between heightened stress and impairments in metacognitive sensitivity. For instance, giving people a small dose of cortisol leads to a temporary spike in this hormone that is sufficient to decrease metacognitive sensitivity compared with people given a placebo. In turn, simply knowing a bit more about the science of self-awareness helps us adopt a more compassionate stance towards similar failures of metacognition in others.

If it were possible to systematically boost self-awareness, what might that feel like? One possible insight comes from work on lucid dreaming, where people are aware of being in a dream. Imaging studies have shown that when people become lucid, they recruit similar brain networks to those that support metacognition while awake.

I find it appealing that boosts to self-awareness in our daily lives might feel like the experience of becoming lucid in a dream – we might notice things we haven't noticed before in ourselves, in others and in our surroundings. These changes may permeate many aspects of our lives, because being self-aware is central to how we experience the world. The kind of consciousness we cherish – the kind that allows us to appreciate the smell of coffee, reflect on the beauty of a sunset or wonder whether our senses are being fooled by magic tricks – involves "meta-awareness", a state of knowing that we are conscious.

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BOX – Your metacognitive fingerprint

Why are some people more self-aware than others? Studies show that metacognition is a relatively stable trait, so if you tested your metacognition today, it is likely to be similar if you do the same test again tomorrow. Strikingly, it also seems that metacognition is independent of IQ and general cognitive ability: your metacognition can still be in good form as long as you recognise you are performing badly at a task. We still don't understand the origins of these individual differences, but one promising idea is that "explicit" metacognition is something we learn, based on feedback from our parents, teachers and social group. A genetic "starter kit" may establish forms of self-monitoring early in life and then our parents and teachers finish the job. But even in adulthood, these things aren't totally fixed (see main story), so this is one kind of fingerprint you can change.