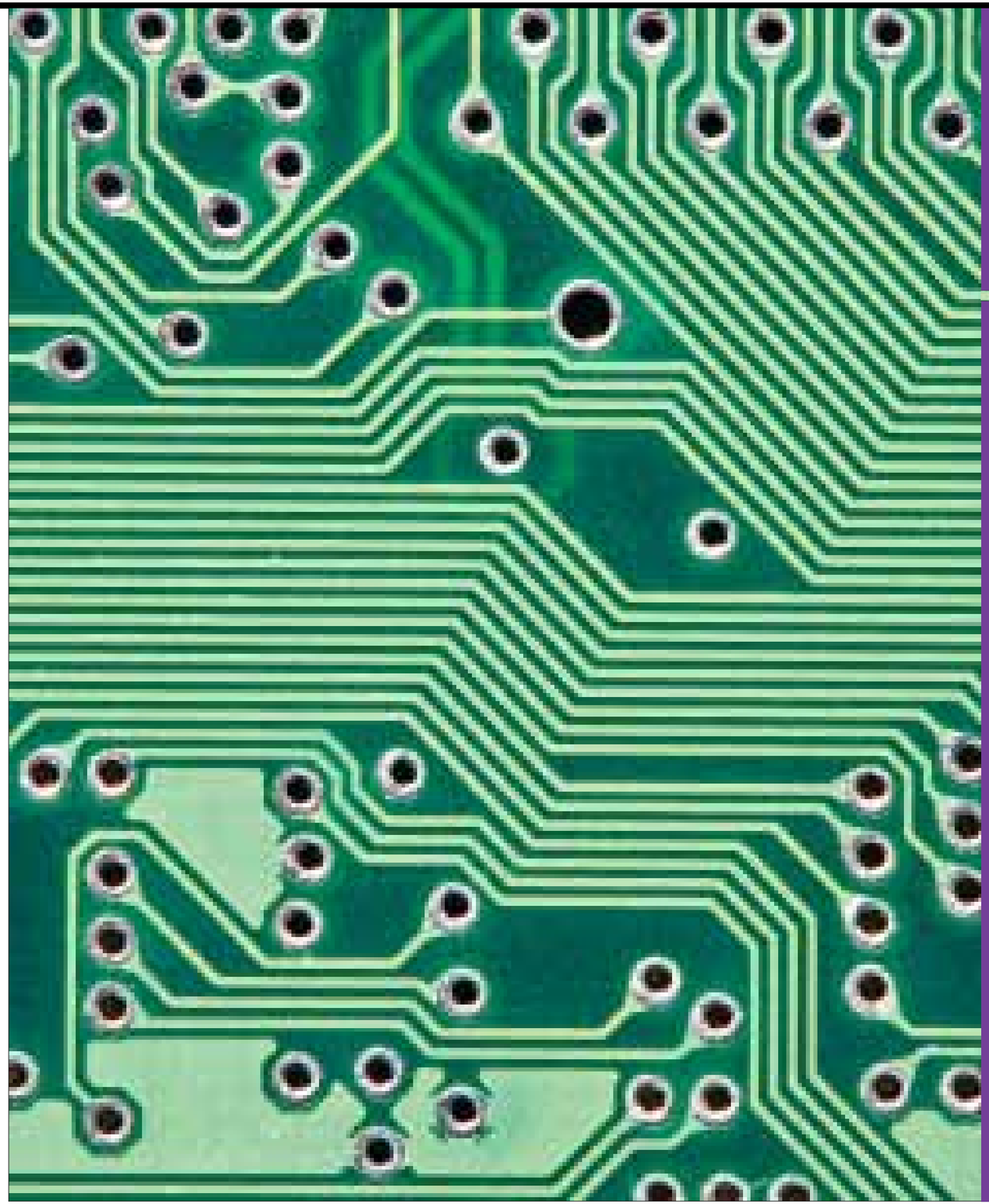


REVISION SPECIAL

The truth about memory

If you want to optimise learning, forget what you think you know about how the brain recalls information and discover how to apply the science of memory in your classroom.
Joseph Lee reports

ALAMY

When you ask Alex Mullen, the 23-year-old winner of the World Memory Championships 2015, how victory felt, he laughs at himself a bit. Because nobody's memory is perfect, right? Mullen had only started to train his memory three years earlier, after seeing a TED talk by the author Joshua Foer that discussed groups of enthusiasts known as "memory athletes" who performed amazing feats, such as memorising thousands of random numbers or hundreds of names in just a few minutes.

What Foer discovered, to his surprise, was that these people weren't savants, nor were they freaks. They all swore that they'd had perfectly ordinary memories until they had started to train them.

That was an appealing message to Mullen, a medical student at the University of Mississippi, who was looking for ways to get a better handle on the huge volume of information he needed to recall. And when he began training, he got hooked on the rapid improvement in his memory and focus.

That training led him to the final day of the three-day World Memory competition last December, where competitors test their minds by memorising numbers, names and faces, historic dates, words and cards in marathon hour-long sessions and quick sprints. Mullen was in second place. He had set a new world record for memorising 3,029 numbers in order over an hour.

One high-pressure round was left: a race to memorise the order of a deck of cards. "It's the fastest and riskiest and scariest event," Mullen says. A decade ago, beating 30 seconds was dubbed the "four-minute mile of memory". Mullen needed 23 seconds or less to win. He made it in 21.5 seconds.

So, how did he feel? "You know," he says, speaking from his home in Mississippi. "It's kind of ironic, but I sort of forget."

Vivid detail

As anyone who has sat an exam will know, the puzzle of memory is that on different occasions it can either restore the past to us in vivid detail or draw an embarrassing blank. In recent years, scientists have made great strides in understanding why this is and how memory works and why it sometimes fails, but outside of that world there remains widespread misunderstanding and disagreement about memory. And what we do know has struggled to find its way into schools.

The "arts of memory" similar to those that Mullen uses were commonplace from the time of the ancient Greeks to the Renaissance – until they were displaced by a machine, the printing press, which propelled the Reformation in Europe and left memory arts seeming like a relic of the medieval past. Now, in the midst of a second information revolution, the perception that memory can be "replaced" by a recording device has grown more pronounced.

However, scientists are increasingly discovering that memory's power lies in processes that don't resemble a machine at all – it's much more complex and interesting than a simple record of what has passed.

"The most common misunderstanding is the idea that memory works like a video recorder or a photograph – maybe not an entirely accurate one, but that memory is basically a recording of what's out there and a reproduction of that experience," says Daniel Schacter, professor of psychology at Harvard University.

But he and many other researchers have found that remembering is a much more active process of construction. The difficulty is not so much in storing information – getting knowledge into memory – but getting it out again when we need it.

Schacter calls failures of memory, such as when something's on the tip of your tongue, "blocking". It's a familiar feeling for those of us who have ever forgotten a name. Schacter says that when this happens to you, it's likely that it is someone you don't deal with very often.

"Studies have shown that the names we tend to block on are the names of people we are somewhat familiar with, but we haven't encountered recently or frequently. There may be not as strong a link between a face and a name for those faces that we block on," he says.

We're less likely to get stuck trying to recall something that comes to mind regularly, and the reason for this may be embedded in the structure of the brain.

"If you think about it briefly and superficially, what could be easier than putting something into something and taking it out again later?" says Michael Rugg, professor of behavioural and brain sciences at the University of Texas in Dallas. But memory is not like that, he says, "it's a phenomenally difficult scientific question."

Rugg says that the standard model of memory – in a simplified form – is that the brain stores experiences and information by adjusting the connection strength of the synapses between neurons. If a group of neurons is activated at the same time, the connection grows stronger. Then the next time any one of these neurons is activated, it's more likely that others in the network will be, too (see box, opposite).

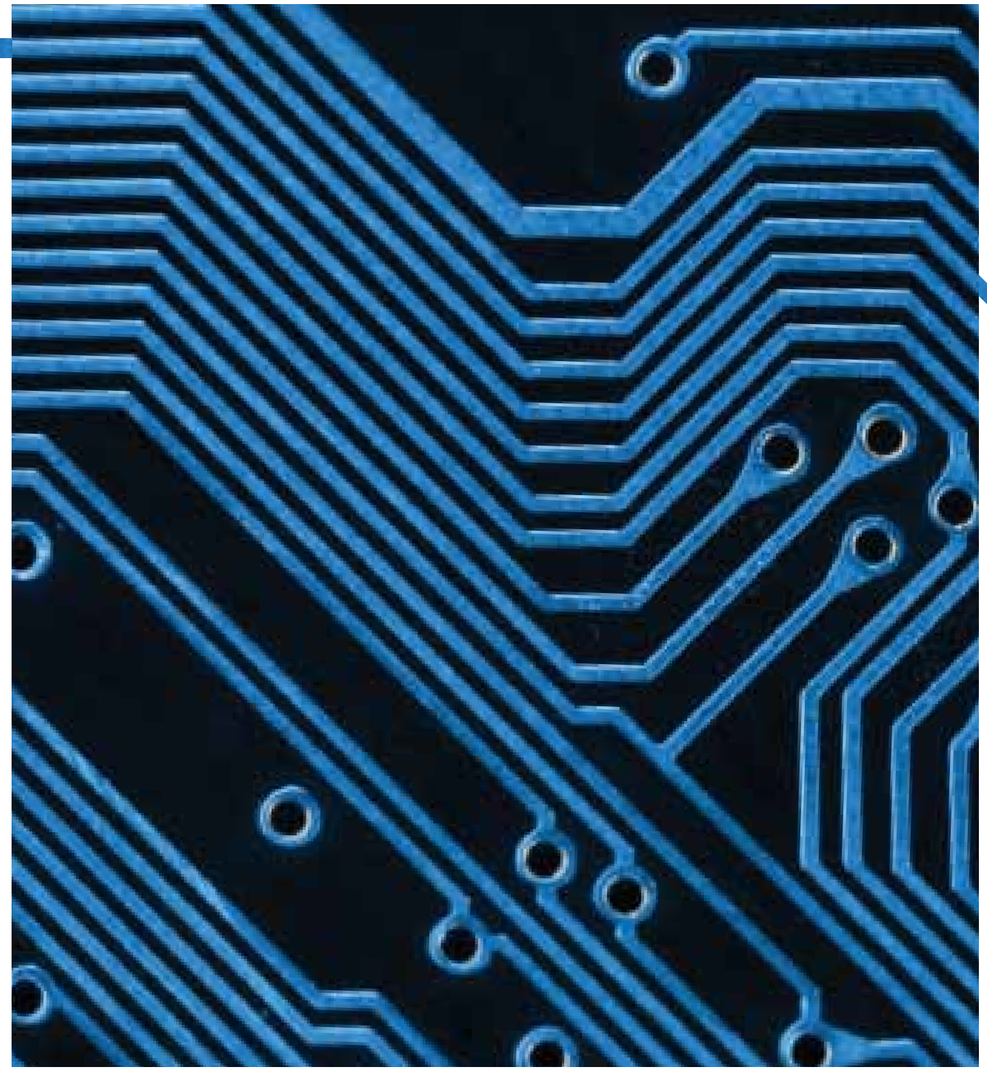
That has two implications: memory is flexible, meaning that it doesn't need precisely the same trigger to recall a fact or experience every time; and reactivating a memory is likely to strengthen the synapse connections and make it easier to recall in future.

It's this last fact that has attracted intense interest from cognitive psychologists. And although it seems like a simple, common-sense idea, the implications of a memory that is strengthened by this effort of retrieval overturn some popular and long-held notions about how we learn.

The 'Learning and Forgetting Lab'

Robert Bjork, professor of psychology at University of California, Los Angeles, calls his laboratory the "Learning and Forgetting Lab". It's a measure of how crucial he regards both processes to the way our brain learns what is important for it to retain.

"You know, if I ask you, 'What's your current phone number or your address?'" he says, "you don't want to do what a lot of computer routines would do and give out ➤



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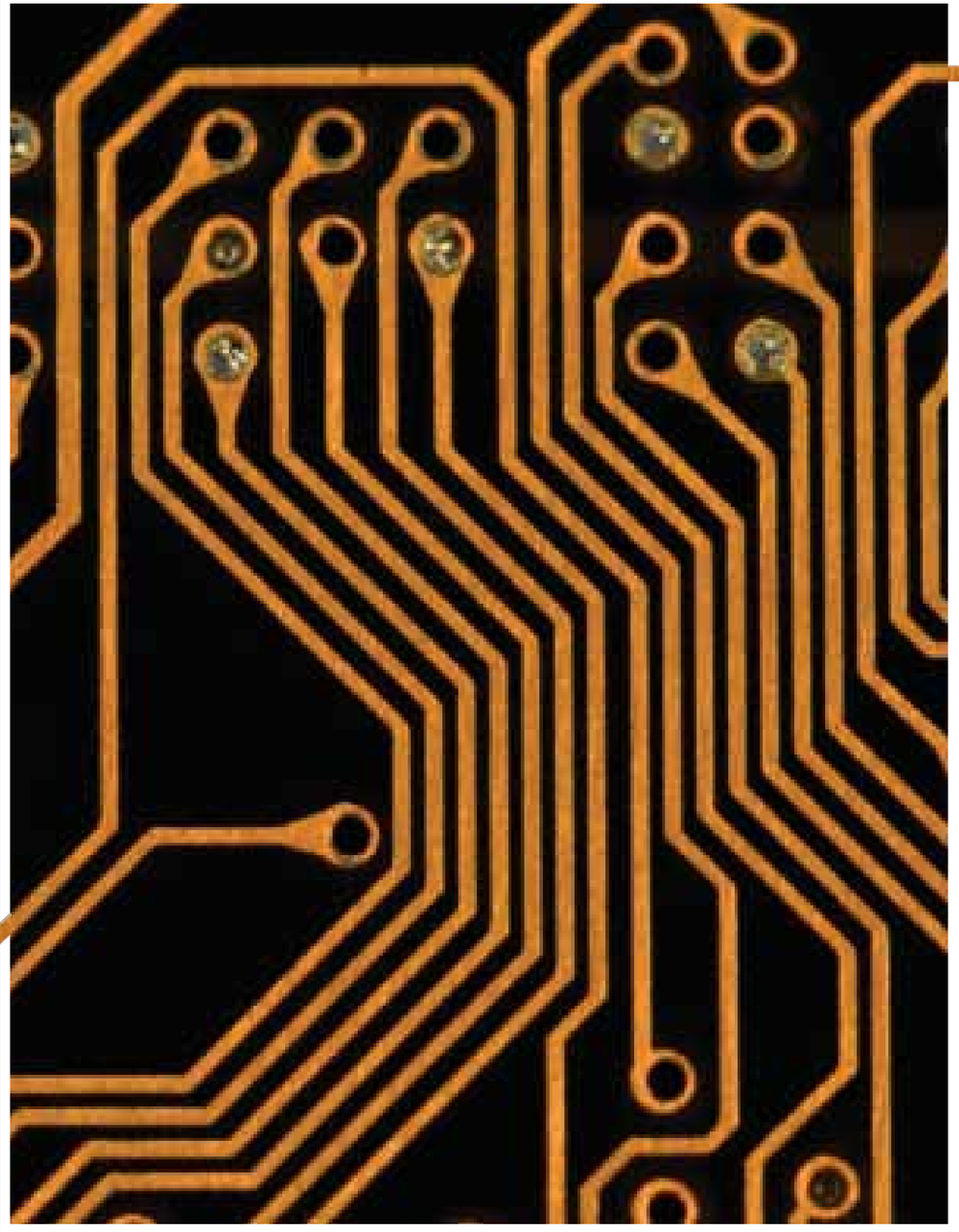
Total recall: how our memory works

- Our memory for facts and events starts with paying attention, because strong memories need good inputs. When we focus on something, we encode information in short-term electrochemical signals between billions of networked neurons. Holding this information in working memory mostly takes place in the prefrontal cortex, a part of the brain involved in executive function. We can retain the information here for a few seconds before it decays, or we can keep refreshing it, but only as long as we don't get distracted.
- Information is transferred to long-term memory by passing through the hippocampus – the area of the brain thought to be the centre of emotion, memory, and the nervous system. It works like a sorting office for the brain, storing just enough information to point to and activate the relevant sites in the neocortex, the outer layers of the brain responsible for sensory perception and conscious thought.
- The hippocampus organises the information from different sensory inputs and compares it with earlier memories. When we are expected to retrieve new facts, such as in a test, we pass them through the hippocampus again, causing gradual and long-lasting changes in connections within the neocortex.
- Eventually, the connections within the neocortex become established so that we can recall the memories that they encode without the intervention of the hippocampus. It becomes part of the quick and effortless knowledge base that encompasses things such as meanings of words, general knowledge or social customs.

'Scientists have made great strides in understanding how memory works'



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Memory tips for learning and revision

- Good input matters – there's no substitute for paying attention.
- Make information more memorable by connecting it to prior knowledge, elaborate on it and translate it to different contexts.
- It's better for students to generate answers themselves than to be told something.
- We're bad at predicting what we'll remember, but testing later tells us what we really know.
- Create 'desirable difficulties' by spacing out tests and interleaving topics.
- Most students prefer bad study techniques: highlighting passages, repeated reading, and cramming the same topic for hours. Encourage them away from these.

a whole load of numbers, and then have some sort of decision process on which one is current. When we stop using something like a phone number, the old one remains there but becomes inaccessible, which means it doesn't interfere. Forgetting is adaptive, not just a weakness."

When we remember something – a phone number, the capital of Bolivia – our mind doesn't simply "reveal" it, but also makes it more retrievable in future. And things that are in competition with it – outdated numbers, last year's test answers – become harder to recall. Your brain imposes a hierarchy on retrieval.

The recommendation for teachers, then, is both familiar and a little surprising: if you want students to remember something, test them often. The attempt to recall the information signals its importance and relevance, and makes it easier to retrieve each time.

As a strategy this is familiar, because tests are a part of every teacher's repertoire. But it's surprising because we think the purpose of tests is assessment, when they turn out to be one of our most effective tools for learning.

"Testing has kind of got this bad name because people think of it in its assessment sense. For example, 'teaching to the test' is a derogatory term," says Bjork. "That's been so unfortunate because quizzes and low-stakes testing are crucial to optimise learning. Testing has to be thought of in a pedagogical sense as well. In fact, in talking to some audiences, I've intentionally used the term 'retrieval practice' to avoid getting into issues of, 'Aren't we testing our students too much?'"

In 1978, research published in the *Journal of Experimental Psychology: human learning and memory* compared one group of students that had repeatedly studied material (cramming) with another that practised retrieval. In an immediate test, the crammers did better. But two days later, they had forgotten half of what they'd learned, while the ones who practised retrieval had forgotten only 13 per cent.

The testing effect appears in the real world of schools, as well as in laboratory tests. In 2006, Columbia Middle School in Illinois agreed to host an experiment by Henry Roediger, a professor of psychology at the University of Washington in St Louis, who, along with co-authors Peter Brown and Mark McDaniel, compiled his insights into memory and education into a book, *Make It Stick: the science of successful learning*.

For a year and a half, students taking part in the experiment followed the social studies curriculum – equivalent to history and geography – with additional ungraded quizzes for a third of the material, extra revision opportunities for another third of the material, and the rest taught as normal. At the end, students achieved a full grade level higher on the material that they had been quizzed on. But in the material where they had just relearned the facts, there was no improvement.

This "truth" about memory has been understood as far back as Aristotle. In his *Novum Organum Scientiarium*, published in 1620, Francis Bacon recommended testing yourself rather than re-reading as the way to learn something by heart. As academic research makes more inroads into schools than ever before, knowledge of such ideas is becoming more common among teachers.

Yet they are still failing to have an impact on how teachers structure learning. Bjork surveyed 500 college students in 2007: "Overwhelmingly, they were not studying in any ideal way, not incorporating these principles," he says. Re-reading and highlighting remain the most common study practices. Almost 10 years after he undertook his survey, the prevailing approach to learning in schools is the same.

Revising revision

But what would schemes of work devised around memory look like? Bjork says that they would promote "desirable difficulties": the counter-intuitive notion that our best learning takes place when we don't feel that the material is particularly familiar. Put into practice, this means that teachers would:

- space out tests rather than cramming in repeated re-readings of a textbook in one long session;
- interleave different topics, returning to them from time to time instead of dealing with them in blocks and moving on;
- ask students to generate their own answers with essays or a few sentences, rather than using multiple-choice tests;
- vary the conditions of practice to prevent learning becoming rote and tied to one context;
- change the test format or the room you study in, often.

"If you take very seriously this evidence on spacing, variation, retrieval practice, introducing contextual interference, and interleaving rather than blocking, your course will be dramatically different from a normal course," says Bjork. "It will look haphazard in certain respects. It really will change it. And the reactions of your students won't be immediately positive. You're doing something that will slow their gains, and people do interpret their current performance as learning."

Some teachers have taken the plunge and are using what we know of memory to structure teaching. William Emeny, head of maths at Wyvern College in Hampshire, is one. Inspired by the evidence from psychology, he analysed the results of 240 students over the course of their GCSE studies. He realised that from Year 9 up to December of Year 11, students were effectively getting blocked practice: learning a topic then moving on to the next.

But over the course of Year 11, they would take a practice paper every week, testing them on material from the whole three years – effectively introducing spaced retrieval and interleaving. The school's data showed a clear effect: students made more than twice the rate of progress in the final six months as they had in the previous two-and-a-half years. That fact inspired a commitment to introduce spaced learning earlier.

As Bjork predicted, students were slow to realise the improvement. "I have had to be adaptive with strategies for student engagement – they like short, quick wins rather than the struggle for effortful retrieval," says Emeny. "The most effective strategy I have found so far is explicitly educating students about the research."

Teachers who upend the curriculum to focus on memory also face objections that memorising isn't the ➤

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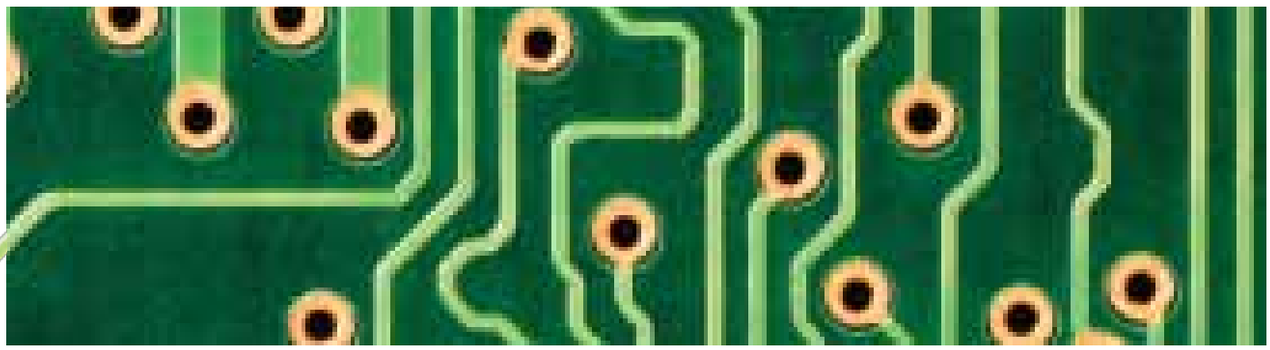

‘If you want your students to remember something, test them often’

same as learning. In fact, rather than rote learning, which resembles the superficial fluency that students achieve from repeated study of material without testing, effective retrieval depends on deep understanding.

The key to building a strong memory is connecting knowledge with prior learning, being able to reproduce it in new contexts, and making it relevant and meaningful. When students ask, “Why do we need to know this?” and “Will it be on the test?” they understand their process of learning accurately. Relevance matters to memory and if people are told that they won’t be tested on information, or that it can be looked up on the internet later, their recall automatically gets worse.

Ace of space

Another teacher who has put memory research into teaching practice is James Paterson. He teaches psychology at LVS Ascot, an independent school in Berkshire. He’s also the two-times Welsh memory champion and, as he puts it, the Goran Ivanisevic of the UK-wide competition (ie, he’s a repeated runner-up).

He uses memory techniques with his students, but he also uses his own experience as a cautionary tale. Part-way through his university course, having newly become a memory master, he started “going to the pub and thinking I had it in the bag because I was an expert memoriser.”

He struggled in exams because he had failed to pick up the analysis and connections that he needed for good essays. Now, as a teacher, he uses the techniques of memory athletes to help students reinforce their understanding of complex concepts.

Memory athletes usually rely on two techniques for this: making abstract knowledge seem more relevant by connecting it to images of people and objects that they already remember, and/or organising the information in mental spaces called “memory palaces”.

At Paterson’s old school near Oxford, colleagues would take students on field trips to the Bodleian while he would sign them out to go to Starbucks. But in reality, it was a trip to a memory palace.

There, students would break down one of their revision topics and assign key facts and concepts to locations in the coffee shop, repeating the system for more than 30 essay topics in different places. These days he uses locations on the school site (see page 42 for tips on how to build an exam-room “memory palace”).

Perhaps the most powerful effect of this, Paterson says, is giving students the confidence that they can organise and retrieve all the information they need, freeing them to think in exams. “That stress-reducing quality is almost the biggest factor of all,” he says.

“All mammals are very good spatial navigators,” says Roediger when explaining why memory palaces work. “What we’re probably doing is hooking in a very old evolutionary ability in that we remember spaces very well.” The hippocampus is sometimes referred to as the brain’s indexing system for memory, but it’s also responsible for spatial navigation.

If you’ve read all this and still have your doubts; if you see memory as opposed to higher-order thinking, then there’s one more thing you should know: the link between recall and creativity is a powerful one. Psychologists have found that the same brain regions involved in memory are responsible for imagining the future. Test subjects who practise recalling detailed memories subsequently perform better at creative tasks.

“One of my old mentors had as his catchphrase, ‘Memory is the bridge from our past to our future’. It’s not our bridge from the past to the present,” says Rugg. “We don’t have memories so that when we’re 60 or 70 years old we can sit on our porches and cheer ourselves up thinking of how happy our lives used to be. Memory exists, like all behaviour, to make us more adaptive in the future.”

Joseph Lee is a freelance journalist. He tweets @josephlee

For more articles in our revision special, see *TES* Professional, starting on page 34

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