The BRAIN

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Issue Two

LEARNING & MEMORY

FROM RESEARCH TO PRACTICE

How memories are made

Top science-based study tips

Do smart drugs work?

Why good teachers matter

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Learning and memory

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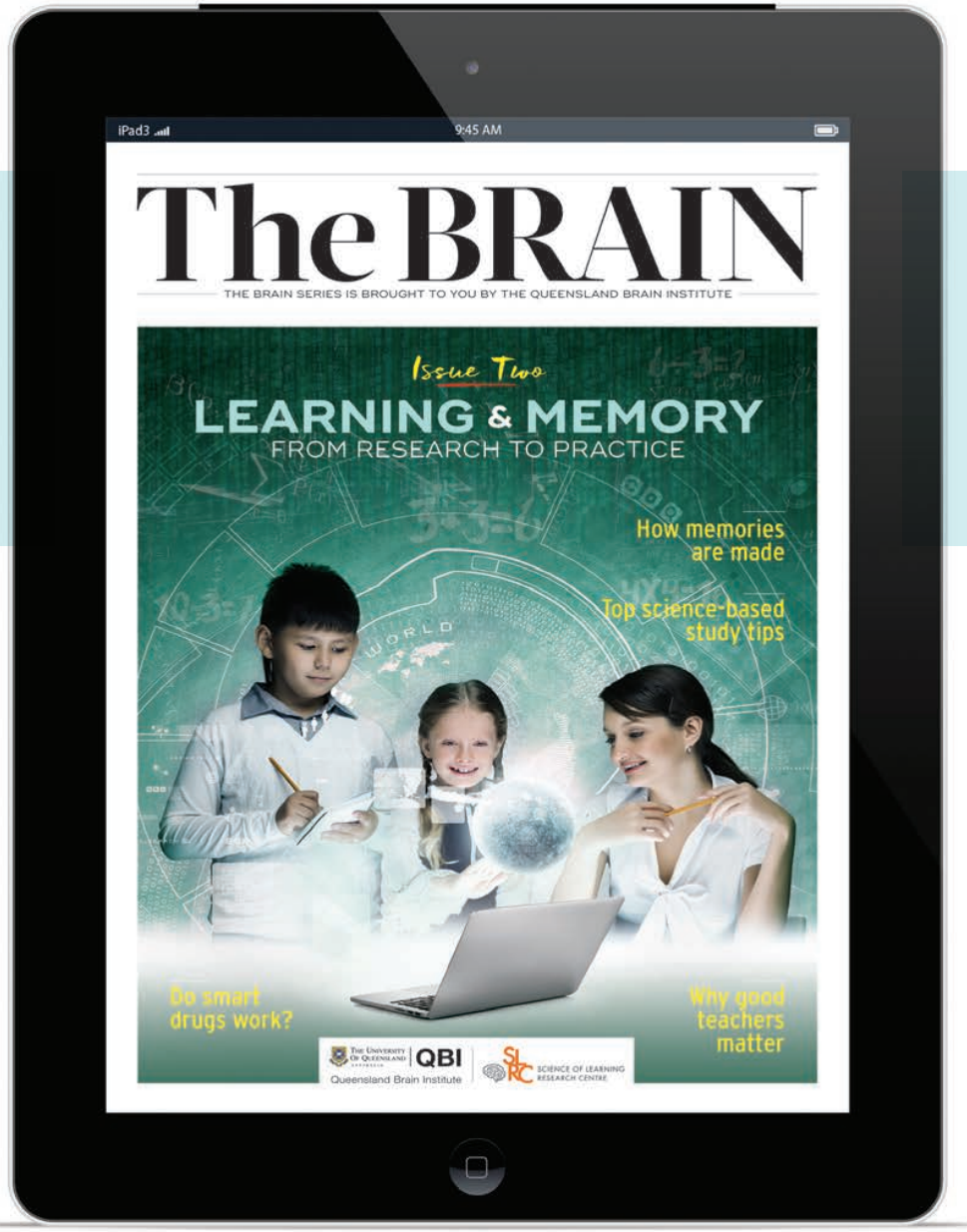

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npj | Science of Learning

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The *npj Science of Learning* Community is an interactive online space for educators, policymakers and researchers to share knowledge, start or join conversations, and read about the latest research into learning.

Accompanying the open access journal *npj Science of Learning*, the Community brings together the findings of neuroscientists, psychologists and education researchers to understand how the brain learns and progresses the aim of the journal to host cross-disciplinary discussions that will help revolutionize learning, memory and education.

Join the education conversation on the *npj Science of Learning* Community – connecting teachers and researchers to understand learning.

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SPRINGER NATURE

A MESSAGE FROM

Professor Pankaj Sah

DIRECTOR OF THE QUEENSLAND BRAIN INSTITUTE AT THE UNIVERSITY OF QUEENSLAND

MAKING AND RETAINING MEMORIES / Issues of health and education

The human brain is a learning machine. Thanks to a phenomenon called neuroplasticity, the brain learns in a range of ways and in many different circumstances, including in the classroom. Because of the importance of classroom learning, educational performance is watched closely by parents, teachers and governments alike. Unfortunately, recent results in Australia suggest that the performance of our students is declining, or has at best plateaued.

Neuroscience and experimental psychology have made great strides in understanding how learning occurs and the factors that influence it, but translating this to education is not straightforward. Part of the problem is an issue of communication: psychologists, teachers and neuroscientists don't always speak the same language. Two recent initiatives aim to bridge the divide between these disciplines. Firstly, the Science of Learning Research Centre (SLRC) – a national, interdisciplinary research centre based at The University of Queensland – has successfully connected with teachers, students and the community to share our knowledge of learning.

Secondly, we at the Queensland Brain Institute (QBI) recently launched an online, open-access journal dedicated to learning – npj Science of Learning, which is helping to bring together the findings of neuroscience, psychology and education researchers.

Importantly, we also want to engage those outside academia – teachers, students, policymakers and the general public. For this reason, the journal has an online npj Science of Learning Community site, where news, opinion and updates on the latest learning research can be found. To these initiatives we now add this publication, which I hope sheds light on the fascinating way our brains learn and remember, and how we can improve these processes.

PHOTOGRAPHY PATRICK HAMILTON

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The Science of Learning Research Centre brings together researchers from neuroscience, cognitive psychology and education

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JOIN THE COMMUNITY
Connecting researchers with teachers and parents to understand and improve how the brain learns.
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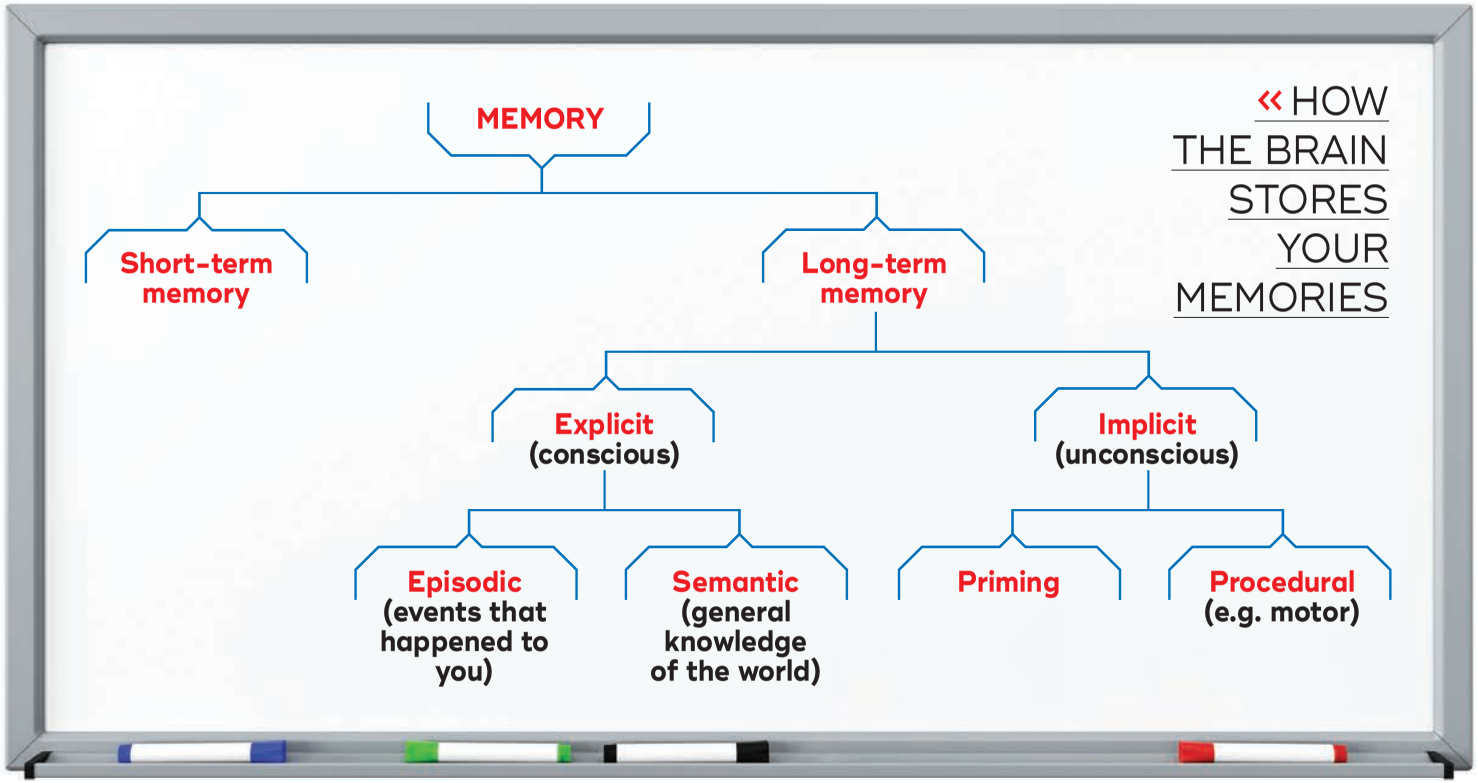
Chapter 1. MEMORIES ARE MADE OF THIS

DEFINING MEMORY

MEMORY IS THE PROCESS OF ENCODING, STORING, AND RETRIEVING EXPERIENCES AND KNOWLEDGE, AND ITS MANY GUISES ARE EVEN MORE IMPORTANT THAN YOU THINK.



It is hard to overstate the importance of memory. It is what makes us who we are. Some memories are the ones we are aware of – the coffee you enjoyed with a friend, that time as a child when the neighbour's dog scared you, knowing that spiders have eight legs, and the indisputable fact that the brain is amazing! These are known as explicit memories – ones we can consciously recall.

But there are also implicit memories, which may be even more important (see below). For example, when you talk, you're using motor memories to move your lips and tongue in a way that reproduces sounds you've learnt. When you walk, you're using motor memories to coordinate your gait.

If we didn't have memories we'd just be a body, unable to communicate or identify danger and – much like a newborn baby – oblivious to how to survive in the world around us.

In short, memory is crucial in transforming us from helpless newborns into capable adults.

SO MANY MEMORIES

There are several different types of memories, some of which are fleeting, and others that last a lifetime.

The shortest type of memory is known as working memory, which can last just seconds. This is what we use to hold information in our head while we engage in other cognitive processes. An example is remembering the numbers a new friend recites as you navigate your phone's menu system to add a contact. A person's working memory capability is one of the best predictors of general intelligence, as measured by standard psychological tests.

While working memory is short-term, *MOST* other categories of memory are *LONG-TERM*.

What we typically think of as memory is explicit memory. This can be divided into episodic memories, which are events that have happened in your life, and semantic memories, which are retained facts or general knowledge.

The other type of long-term memory is unconscious, or implicit. These are memories you can't consciously bring to mind, but which shape your behaviour. The most common type of implicit memory is procedural: this is concerned with how actions are performed, like how to ride a bike or play guitar.

WHERE ARE MEMORIES FORMED AND STORED?

Memories aren't stored in just one part of the brain. Different types are stored across different, interconnected brain regions. For explicit memories – which are about events that happened to you (episodic), as well as general facts and information (semantic) – there are three important areas of the brain: the **hippocampus**, the **neocortex** and the **amygdala.** Implicit memories, such as motor memories, rely on the basal ganglia and cerebellum. Short-term working memory relies most heavily on the prefrontal cortex.

THE NEED FOR SLEEP

WHILE WE SLEEP, the hippocampus and neocortex take part in a carefully choreographed interaction during which the hippocampus replays recent events. The same neurons active in the hippocampus during an experience become activated again during slow-wave sleep, also known as deep sleep. This occurs repeatedly, helping to update the neocortex about what needs to be stored. Replay occurs during sleep, so if you aren't getting enough sleep, you aren't letting your brain consolidate memories.

DID YOU KNOW?

SLEEP HELPS RETAIN MEMORIES. "...so if you aren't getting enough sleep, you aren't letting your brain consolidate memories."

THE BRAIN
OUR MEMORY BANK

EXPLICIT MEMORY

Hippocampus

The hippocampus is where episodic memories are formed and indexed for later access. Episodic memories are autobiographical memories from specific events in our lives, like the coffee we had with a friend last week.

Neocortex

The neocortex is a sheet of tissue that forms the outer surface of the brain. Over time, information from certain memories that are temporarily stored in the hippocampus can be transferred to the neocortex as general knowledge – things like knowing that coffee provides a pick-me-up. Researchers think this transfer from hippocampus to neocortex happens as we sleep.

Amygdala

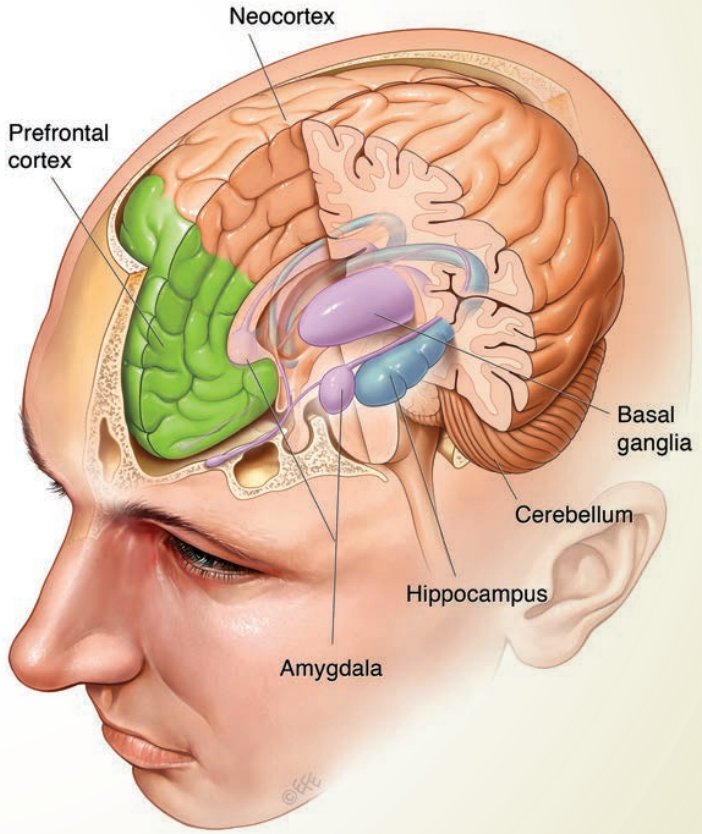
The amygdala attaches emotional significance to memories. This is particularly important because strong emotional memories (e.g. those associated with shame, joy, love or grief) are difficult to forget. The permanence of these memories suggests that interactions between the amygdala, hippocampus and neocortex are crucial in determining the 'stability' of a memory – that is, how effectively it is retained over time.

IMPLICIT MEMORY

Basal ganglia and cerebellum

The basal ganglia are structures lying deep within the brain and are involved in a wide range of processes such as emotion, reward processing, habit formation, movement and learning. They are particularly involved in co-ordinating sequences of motor activity, as would be needed when playing a musical instrument, dancing or playing basketball. The basal ganglia are the regions most affected by Parkinson's disease. This is evident in the impaired movements of Parkinson's patients.

The cerebellum, a separate structure located at the rear base of the brain, is most important in fine motor control, the type that allows us to use chopsticks or press that piano key a fraction more softly. A well-studied example of cerebellar motor learning is the vestibulo-ocular reflex, which lets us maintain our gaze on a location as we rotate our heads.



WORKING MEMORY

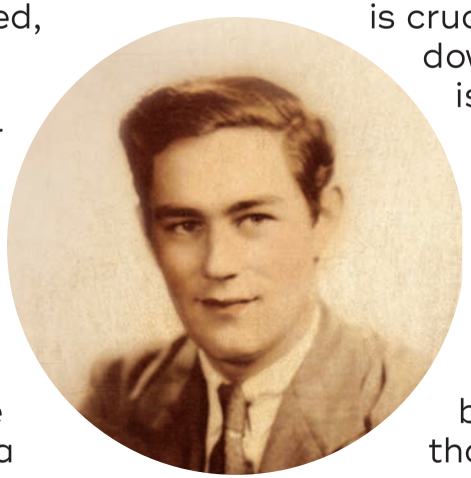
Prefrontal cortex

The prefrontal cortex (PFC) is the part of the neocortex that sits at the very front of the brain. It is the most recent addition to the mammalian brain, and is involved in many complex cognitive functions. Human neuroimaging studies (using magnetic resonance imaging - MRI – machines) show that when people perform tasks requiring them to hold information in their short-term memory, such as the location of a flash of light, the PFC becomes active. There also seems to be a functional separation between left and right sides of the PFC: the left is more involved in verbal working memory while the right is more active in spatial working memory, such as remembering where the flash of light occurred.

MEDICAL ILLUSTRATION: LEVENT EFE

LIVING LESSON

In 1953, **Henry Molaison** had his hippocampus surgically removed during an operation in the United States to treat his epilepsy. His epilepsy was cured, and Molaison lived a further 55 healthy years. However, after the surgery he was only able to form episodic memories that lasted a matter of minutes; he was completely unable to permanently store new information. As a result, Molaison's memory became mostly limited to events that occurred years before his surgery, in the distant past. He was, however, still able to improve his performance on various motor tasks, even though he had no memory of ever encountering or practising them. This indicated that although the hippocampus is crucial for laying down memories, it is not the site of permanent memory storage and isn't needed for motor memories.



The study of Henry Molaison was revolutionary because it showed that multiple types of memory existed. We now know that rather than relying on the hippocampus, implicit motor learning occurs in other brain areas – the basal ganglia and cerebellum.

DID YOU KNOW?

Henry Molaison is one of the most famous patients in neuroscience. After surviving experimental neurosurgery for seizures, he was left with severely impaired memory and went on to became a living test subject for five decades, until his death in 2008

Fear Factor

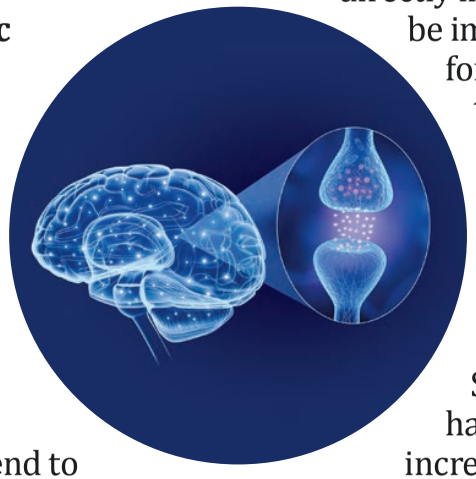
THERE'S AN additional aspect to the amygdala's involvement in memory. The amygdala doesn't just modify the strength and emotional content of memories; it also plays a key role in forming new memories specifically related to fear. Fearful memories are able to be formed after only a few repetitions. This makes 'fear learning' a popular way to investigate the mechanisms of memory formation, consolidation and recall. Understanding how the amygdala processes fear is important because of its relevance to post-traumatic stress disorder (PTSD), which affects many of our veterans as well as police, paramedics and others exposed to trauma. Anxiety in learning situations is also likely to involve the amygdala, and may lead to avoidance of particularly challenging or stressful tasks.

HOW MEMORIES ARE FORMED

THE BRAIN CONSTANTLY SIMMERS WITH ACTIVITY AS DIFFERENT GROUPS OF NEURONS, DRIVING OUR DIFFERENT THOUGHTS OR PERCEPTIONS, DRIFT IN AND OUT OF ACTION LIKE FIREFLIES IN A FOREST.

A memory is the reactivation of a specific group of neurons. But what allows a specific combination of neurons to be reactivated over any other combination of neurons?

The answer is **synaptic plasticity**. This term describes the persistent changes in the strength of connections – called synapses – between brain cells. These connections can be made stronger or weaker depending on when and how often they have been activated in the past. Active connections tend to get stronger, whereas those that aren't used get weaker and can eventually disappear entirely. This gives added meaning to the term ***use it or lose it***! Not many features of the brain are more important than synaptic plasticity.



Changing the strength of existing synapses, or even adding new ones or removing old ones, is critical to memory formation. But there is also evidence that another type of plasticity, not directly involving synapses, could be important for memory formation. In some parts of the adult brain, such as the important memory structure known as the hippocampus, brand new neurons can be created in a process called **neurogenesis**. Studies in older mice have shown that by increasing neurogenesis in the hippocampus, memory can be improved. In humans, exercise has been shown to increase the volume of the hippocampus – suggesting new neurons are being created – and at the same time improve performance in memory tasks.

Memory Pathways

A GOOD ANALOGY for memory formation is the way foot traffic creates a path along a stretch of grass. The more a patch of grass is trampled as people pass along it, the clearer the path becomes and the easier it is to follow – it's as if a 'memory' of all the walking has been created. The same thing happens in the brain. The more a neural pathway is activated, the stronger the synaptic connections along the way become. Then, when a thought enters our head – say, a tropical beach – we recall related experiences or knowledge, such as putting on sunscreen and the feel of sand, as our minds funnel our thoughts along well-established neural pathways.

HOW MEMORIES ARE ACCESSED

YOUR EXPERIENCES IN THE WORLD ARE BASED ON INFORMATION RECEIVED THROUGH A COMBINATION OF SENSES: SIGHT, TOUCH, HEARING, TASTE AND SMELL.

A memory of the coffee you had with a friend last week, for example, could include the taste and smell of the coffee, the café's interior design, the sound of an ambulance's siren as it drove past, and the topics of conversation you discussed. These components of your experience would have activated various parts of your neocortex. But the episode itself would initially be stored in the hippocampus. Over time this memory is consolidated, with its long-term storage thought to be distributed in different parts of the neocortex.

Once A memory has been stored, how is it accessed?

According to one popular theory, the hippocampus is critical, serving as a memory index. To use an analogy: when functioning well, memory is like a digital database or an old-school-style office filing cabinet: something triggers a search of the database, and we retrieve and recall the memory.

Returning to our café story, when your friend mentions how much she liked the café's stylish interior, you picture the inside of the café, making your visual cortex – the part of the brain that receives and processes sensory nerve impulses from the eyes – become active in a similar pattern to when you saw the café first-hand. Because of synaptic plasticity and strengthened connections (see previous page), this visual seed is enough to access the 'café with friend' scene in the hippocampus's index. To actually recall the memory, the hippocampus then directs neuronal traffic back to the appropriate circuits of the neocortex, reactivating the sound of the ambulance siren, the taste of the coffee, the topics of conversation and any other components of the 'café with friend' memory.

This idea of memory indexing and recollection is still only a theory.

PROFILE

THE POWER OF POSITIVE

THIS ACCLAIMED EDUCATOR IS PROVING THAT OPTIMISM AND AFFIRMATION BRING FAR GREATER RESULTS IN THE CLASSROOM THAN NEGATIVE FEEDBACK.

Dr Chris Sarra is an educator who has dedicated his career to shifting expectations around children in schools across Australia. His focus has been Indigenous children and he's managed to break through entrenched misunderstandings and use education to make a real difference to their lives.

"The key has been getting educators to embrace Aboriginal kids beyond the stereotypes that dominate the landscape, while also allowing the kids themselves to see outside these labels," says Chris, Founding Chairman and CEO of the Stronger Smarter Institute, which has been operating for a decade now to improve educational outcomes for Indigenous Australian schoolchildren.

Chris believes that constant criticism and negativity may have a fundamental impact on the way children learn. "From a neuroscience perspective, I am particularly interested in the impact on the wiring of the brain when it is constantly bombarded with negative messages," he explains. "The essence of being stronger and smarter is to have a positive impact on a child's psyche and provide an authentic reason to be more optimistic.

"Advances in research relating to the neuroplasticity of the brain take this thinking from a 'romantic' notion to a clinical level, which is a great advancement."

Growing up in Bundaberg in the 1970s as the youngest of 10, Chris had first-hand experience of the many negative issues faced by Indigenous students during schooling, including racism and low expectations. "Sometimes I would sell myself short," he admits. "But I grew up with a very strong and proud mum, who, in many ways, created a force-field around our family, always giving us a strong and positive sense of what it meant to be Aboriginal. Her constant message was *never become a victim of racism."*

This drove Chris to teachers' college and the first steps in the career in education that is now his passion. "My college lecturer, Dr Gary MacLennan, mentored me and at one point grabbed me by the 'intellectual scruff of my neck', calling upon my sense of outrage and determination to not defer to what people expected of me," he says, recalling that this gave him the self-confidence to believe he could succeed.

After qualifying as a teacher, in 1998 Chris became the first Aboriginal principal at Cherbourg State School in South East Queensland. There he developed the 'Stronger Smarter' philosophy, which encouraged Indigenous students to be both strong in their cultural identity and smart about making the most of educational opportunities.

"Throughout my education, I developed a sense of understanding that if I changed my expectation of who I am, I could transcend the stifled beliefs of where I could go," Chris says. "We achieved success at Cherbourg through flushing out the negative stereotypes and replacing them with a positive cultural identity while also challenging the whole school community to have high expectations of Indigenous students."

More at strongersmarter.com.au. Chris's book, Good Morning, Mr Sarra, *is available at uqp.com.au or at all good bookshops.*

PHOTOGRAPHY BY ERIKA FISH

PHOTOGRAPH ERIKA FISH

Chapter 2. HOW WE LEARN

LEARNING STYLES: exposing the myths

ARE THERE SUCH THINGS AS 'VISUAL LEARNERS' OR 'AUDITORY LEARNERS'? WHAT DOES THE SCIENCE SAY?

The idea that different people have different learning styles is actually a misconception that has become widespread. A 2012 survey of teachers from the Netherlands and the United Kingdom, for example, found that more than 90% believed in different learning styles. In fact, although people may have personal preferences as to how they take in information, it's untrue that an individual learns better through any one particular set of sensory cues.

In 2008, an extensive review by cognitive psychologist Dr Harold Pashler and colleagues from the University of California, San Diego assessed decades of research and found no evidence to support the idea that an individual learns more effectively when teaching is tailored to a particular style.

The misconception that they do

"is based on a valid research finding, namely that visual, auditory, and kinaesthetic information is processed in different parts of the brain," explained the authors of the UK–Netherlands study. During learning, as in many other brain activities, these brain areas work with each other rather than in isolation. There is no evidence, however, that these areas work 'better' in some people than others to determine overall how each person learns best.

Why good teachers matter

WHEN IT COMES to learning, the importance of great teachers can't be underestimated, not least because teachers have a significant influence on student achievement. Almost everyone can name a teacher who stands out in their memory because they were particularly engaging, encouraging or inspiring.

Using data from more than 500,000 studies, Professor John Hattie, Director of the Melbourne Education Research Institute at the University of Melbourne and a lead investigator in the Science of Learning Research Centre, conducted a meta-analysis and ranked various influences on student learning and achievement. He found that the impact teachers have on student learning is greater than other factors that often dominate public debate, such as class size, technology, individualised instruction, streaming by ability and changing school calendars or timetables.

The influences with the most effect, by far, were teacher-related: both teachers' expectations for their students and their level of expertise topped the list. For teachers to inspire students, they need to make the effort to understand their own impact and what methods work best in the classroom. In contrast, Prof Hattie found that repeating students, and teachers who have low expectations or label their students according to ability, have low or even negative impacts on learning achievement.

THE POWER OF SPEECH

A RARE GROUP OF PEOPLE KNOWN AS POLYGLOTS ARE ABLE TO USE MULTIPLE LANGUAGES.

What's their secret? Is their ability with languages simply due to persistence, or do their brains work differently to give them an advantage in this area?

Emil Krebs, a 19th century German polyglot, was reportedly able to speak and write 68 different languages. A post-mortem study of his brain found anatomical differences in Broca's region, an area of the frontal lobe important for speech production. Researchers were unable to determine, however, whether the structure of his brain was unique from birth, or resulted from his language learning.

Other research supports the idea that brain anatomy does contribute in some way to language learning. A study by Northwestern University researchers found that having a larger left Heschl's gyrus – a brain region known to be involved in processing pitch – was associated with more success in learning foreign pitch patterns. But Heschl's gyrus is just part of the story. Speech relies on connectivity between many regions of the brain, and success at learning a language depends on multiple factors including literacy in your native language, general verbal intelligence and the age at which you first learn the foreign language.

DID YOU KNOW?

IT COULD BE worth dusting off those old French textbooks from high school! Research suggests bilingualism contributes generally to the maintenance of a healthy brain. Neuroplastic brain changes, including increased grey matter density, have been found in people with skills in more than one language, from children and young adults through to the elderly. Such changes even occur with short-term learning. And at least one review has found that lifelong bilingualism is associated with an average delay in the onset of dementia by four years.

BOOST YOUR LEARNING

USE THESE SIX TIPS TO HELP IMPROVE THE POWER OF YOUR BRAIN.

1. MINIMISE DISTRACTIONS

"The easiest and most obvious way we can help to focus our attention is by reducing the amount of distractions in our environment."

That's the advice of QBI cognitive neuroscientist Professor Jason Mattingley. Distractions include mobile phones, social media and television.

Multitasking should also be avoided, where possible. Although some people are convinced they can do two or more mental tasks equally effectively at the same time, research shows this isn't the case. Multitasking activates inhibitory networks in the brain, which suggests the brain is rapidly switching between tasks rather than doing them simultaneously. Other research has found that chronic multitasking impairs both long-term and working (short-term) memory.

EDUCATORS

Set rules about the use of technology in the classroom; encourage students to focus on one task at a time.

2. USE ACTIVE TESTING OR RECALL

Doing quizzes or forcing yourself to actively recall information is linked to deeper memory formation than when you passively review notes. US research involving a foreign language learning task, for example, found that university students were better able to retain word meanings if they were actively tested on them, suggesting long-term learning occurs during forced-recall testing.

EDUCATORS

Make quizzes or assessment tools available to students.

3. SPREAD LEARNING OUT

The benefits of spacing out learning have been observed in students from pre-school to university. For long-term retention, spacing study sessions apart is far more effective than when information is learned en masse in one long session. Revise regularly, whether it is done weekly or each day.

EDUCATORS

Periodically review topics throughout a term.

BOOST YOUR LEARNING

USE THESE SIX TIPS TO HELP IMPROVE THE POWER OF YOUR BRAIN.

4. MIX THINGS UP

In a traditional and widely applied approach to learning known as 'blocking', skills are taught sequentially and you don't move onto a new one until you've mastered the previous one. But it's now known that mixing up the practice of several interrelated skills can boost performance in the long run. Known as 'interleaving', it's long been established that it can improve motor learning, such as for tennis or piano players. A growing body of research is showing that it also has applications in the classroom.

EDUCATORS

Intermix step-by-step worked solutions with problem-solving exercises, or provide students with revision material that combines practice questions about multiple topics.

5. COMBINE SPOKEN WORD WITH IMAGES

The brain's visual and auditory processing centres are located in distinct regions and activated separately when we see images and hear words. While multitasking is detrimental to learning, research has found that processing images and spoken words simultaneously has no negative effect on how well we remember them. The same, however, is not the case for images and visual text: when you try to listen to a speaker while reading something unrelated at the same time, neither is well understood.

EDUCATORS

Use relevant non-text images as teaching aids, in the form of large presentation visuals or image-based handouts.

6. USE STORIES

How well you remember an abstract concept can be improved by concrete examples or stories. After forming a memory, we need to consolidate it to make it last longer. This is easier when there's context to the information being learned. This is why memory aids – mnemonics – are useful when studying.

Mnemonics and stories help you form associations between the content you want to remember, and the story you recite. These associations are strengthened neural pathways, formed by synaptic plasticity, so that when you think of one (the story or mnemonic), you more easily recall the content you actually care about. The mnemonic Every Good Boy Deserves Fruit, for example, gives the five musical notes on the lines in the treble clef, EGBDF. If you're studying medicine or nursing, you're likely to remember the cause of a disease that has affected someone you care about – a personal story contextualises the memory and enhances its meaning.

EDUCATORS

Provide context, real-world examples, or stories for concepts being taught.

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Chapter 3. FACTORS AFFECTING LEARNING

TECHNOLOGY: good or bad for learning?

SMARTPHONES, TABLETS, HIGH-SPEED INTERNET AND SOCIAL MEDIA HAVE CHANGED THE WAY WE LEARN.

With the rise of digital alternatives, the use of paper textbooks has all but disappeared. So, is reading electronically different to reading print? Some experiments have found no difference in comprehension. But in one study, when reading time was self-regulated rather than fixed, participants performed better after reading print. A 2013 US study of university students also found that reading on paper was less likely to encourage multitasking, and that has already been established as a clear advantage when it comes to learning (see p12).

But digital technology has also revolutionised education in positive ways. The internet has brought free access to virtually unlimited troves of information. With the rise of video tutorials and free massive online open courses (MOOCs), education barriers are lower than ever. Multimedia in the form of images, videos and audio resources enrich and reinforce learning. They make experiences such as a virtual tour of China's Great Wall or a video of Martin Luther King's I Have a Dream speech just a few keyboard strokes away.

Interactive game-based learning programs have been found to be effective for teaching. "The gaming approach was both more effective in promoting students' knowledge of computer memory concepts and more motivational than the non-gaming approach," wrote the author of one University of Thessaly study of high-school computer science students.

Assistive technologies have also improved education for students with learning disorders or sensory impairments such as deafness or blindness. Many visual and audio aids, such as speech recognition and text-to-speech software, now exist to help students with specific impairments.

The bottom line is that *TECHNOLOGY IN THE CLASSROOM IS HERE TO STAY*, and when distractions are minimised, *IT CAN IMPROVE AND ENRICH LEARNING.*

Is cramming worth it?

Overstretched students often rely on the time-saving strategy of cramming for exams, but the science says this study technique is highly flawed. Many experiments have shown that 'spacing', which involves spreading study sessions apart, leads to far superior results when it comes to long-term retention. In fact, one 2009 study found that spaced learning was more effective than cramming for 90% of participants.

Memories fluctuate according to changes in the strength of connections – synapses – between neurons. These can be made stronger or weaker depending on when and how often they are activated, meaning that a memory can be reinforced or forgotten. The more these synapses are activated, the more likely the information will be retained, which explains why revision of previously studied material is preferable to learning it for the first time en masse before an exam.

Last-minute cramming usually goes hand-in-hand with stress and a lack of sleep, both of which can hinder learning retention. Sleep is thought to be involved in creating long-term memories by consolidation; deprivation leads to decreased activity in the hippocampus and poorer recall of 'declarative' memories, which are about facts and events. In a study of high-school students, UCLA researchers found that sacrificing sleep for extra study time was counterproductive and resulted in increased academic problems the following day.

THE UPSIDE OF STRESS AND CONFUSION

YOU'RE MORE LIKELY to remember something you've learned if you have an emotional attachment to it. This happens because the amygdala boosts memory by enhancing attention and perception. It can also help memory retention by triggering the release of stress hormones. QBI researchers have discovered that bad experiences automatically enhance memory formation about places and may serve as a cue to avoiding potential threats. Conversely, too much stress can overwhelm, cause anxiety and impair memory – but research has found that the right amount can optimise alertness and cognitive performance.

Surprisingly, even confusion can be beneficial to learning. Research has shown that being confused about new ideas or a situation can spur us to work harder to understand, leading to a deeper grasp and better retention of what we have learned.

HOW DEVICES AFFECT SLEEP

A large body of evidence now shows that the blue light emitted by smartphones, tablets and computers suppresses melatonin production, meaning that using these devices at night can interfere with the body's natural sleep cycles. Sleep is known to be important for learning – it's crucial for consolidating long-term memories. Missing out on sleep can also impair attention and short-term memory.

The teenage brain is particularly sensitive to the effects of blue light. That's why experts now recommend that teenagers should avoid late-night use of devices that emit blue light if they want to get enough sleep.

SMART DRUGS

PHARMACEUTICAL WAYS TO IMPROVE LEARNING MAY BE RISKY.

Ever thought about taking a drug to improve your ability to learn? Chances are, you already do: caffeine. By blocking the action of adenosine, a natural brain chemical that promotes sleep, caffeine – the world's most popular psychoactive drug – prevents drowsiness. It's one example of a group of compounds known as cognitive enhancers, nootropics or smart drugs, which enhance cognitive functions including memory, motivation or creativity. Some of the newest substances being used as 'smart drugs' are medically prescribed for other conditions. For example, methylphenidate, commonly known as Ritalin, is used to treat attention deficit hyperactivity disorder (ADHD). So is Adderall, a combination drug containing two forms of amphetamine.

These are among a suite of pharmaceuticals now being used by healthy people, particularly university students, to enhance their capabilities for learning or working. So, do they actually work? One of the most studied is modafinil, a wakefulness drug approved by the Australian Therapeutic Goods Administration to treat the sleep disorder narcolepsy. Modafinil's beneficial effects in sleep-deprived people are well-known. A 2015 research review by University of Oxford neuroscientists noted that modafinil's neuroenhancing effects varied: the longer and more complex a task was, the more consistently the drug improved cognitive function. Ritalin and Adderall have also been reported to enhance performance in healthy individuals, although research indicates that their effects are modest. However, there are serious concerns relating to the safety and effectiveness of these drugs with both short- and long-term use. Misuse of these amphetamine-based drugs increases the risk of sudden death and heart attack, and there are legal restrictions on their supply and importation. So far, these so-called 'smart drugs' are approved only at specific doses for specific conditions, such as narcolepsy and ADHD.

Should universities consider *DOPE TESTING* to check that students aren't gaining an unfair advantage through drug use?

There are significant concerns about what their impacts may be when used by healthy people, potentially at levels outside prescription doses. Because these drugs modulate important neurotransmitter systems such as dopamine and noradrenaline, users take significant risks with unregulated use. There has not yet been any definitive research into modafinil's addictive potential, how its effects might change with prolonged sleep deprivation, or what side effects are likely at doses outside the prescribed range. Ethical issues also arise with the use of drugs to boost brain power. Their use as cognitive enhancers isn't currently regulated. But should it be, just as the use of certain performance-enhancing drugs is regulated for professional athletes? Should universities consider dope testing to check that students aren't gaining an unfair advantage through drug use?

Until appropriate research has been done, the medical consensus is that you'd be smart to avoid smart drugs.

PROFILE

A SECOND CHANCE AT LEARNING

DISTRACTED BY A DIFFICULT HOME LIFE, **JULIE-ANN LAMBOURNE** NEVER GOT THE CHANCE TO LEARN MUCH AT SCHOOL. . . BUT SHE CERTAINLY MADE UP FOR THAT LATER.

As the CEO of enVizion Group Inc, an organisation dedicated to improving access to education and employment, Julie-ann Lambourne knows a thing or two about teaching and training. She's now had a successful career with more than two decades of State and Federal government experience – but she herself had far from a straightforward education.

A Torres Strait Islander woman hailing from Mabuiag and Darnley Islands, Julie-ann grew up in Cairns in a family experiencing intense social and financial stress. She doesn't recall much of her schooling experience other than "really struggling with the learning process" and left school before completing year 10. "When I told my maths teacher that I was going to leave, he said, 'Yeah, I'm not surprised. You're not cut out for learning'," she remembers. "When your home life isn't great, school is low on your priorities."

"Regardless of where people come from or what their circumstances are, everyone has the ability to learn."

Julie-ann's mother was a chronic alcoholic, and despite having a strong extended family network, had no close role models to look up to. "We practically grew ourselves up," she says. After leaving school, Julie-ann did a few odd jobs. But it wasn't long before she'd enrolled in TAFE to do an associate diploma of early childhood education and surprised even herself when she began excelling in study. By the age of 18 she'd begun a traineeship in the public service and hasn't looked back.

"My path to higher education didn't start until 17 years ago, when I was doing social services work," Julie-ann explains. At the time, she was working with homeless and at-risk youth. "I knew I needed to do extra study to upskill and change my brain's ways of thinking. Many of their stories were so similar to my own, which I had great empathy for, but would personalise in my own mind, at times causing me to regress. Studying helped me to differentiate between self and client."

Julie-ann strongly believes that "regardless of where people come from or what their circumstances are, everyone has the ability to learn." And that's the philosophy that drives her work at enVizion. The group provides training and education to people of all ages and backgrounds. "We structure support around differing abilities so that all people have an opportunity to gain an education," Julie-ann says. "To help our students succeed, we let them know they have people they can rely on and look up to."

PROFILE

GRADE 12 AND MAKING THE BIG DECISION

THE FINAL YEAR OF HIGH SCHOOL BRINGS ITS CHALLENGES, BUT FOR STUDENT J**EREMY MARKEY** THE KEY TO SUCCESS IS BALANCE AND ORGANISATION.

As a year 12 student, Jeremy Markey is close to finishing his educational journey at school. Despite juggling the responsibilities of being prefect at Anglican Church Grammar School (Churchie) with aiming to achieve a good OP, he is finding that his last year as a school student is living up to his expectations.

"I probably experienced anxiety around exams in younger years but cope a lot better with the pressure in Senior," says Jeremy. "I think the key to minimising stress is being organised, and good planning."

"The teachers at Churchie have helped us to transition well from grade 11 to 12. It's all about knowing what's ahead each term and asking for help if you need it."

"I'm lucky that we have a great cohort of boys who willingly support and help each other so we can achieve the best we can academically."

How does he cope with the academic pressures of his final year of high school? "I think it's important to have a good balance between study and other activities including sport which helps you maintain focus, especially in grade 12," he says.

"Early in Grade 11, I found the distraction of having my iPhone where I studied meant I wasn't studying effectively. I decided to leave my phone in the kitchen when I studied and allow myself regular breaks when I can check social media or messages from friends. This has worked really well in keeping me on track without losing touch."

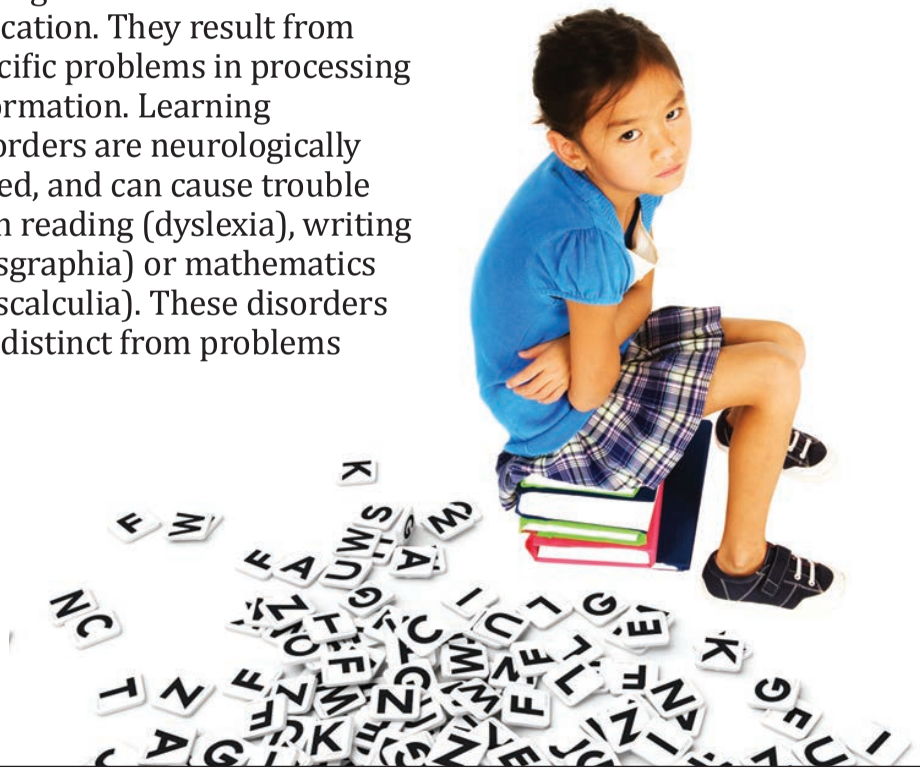
As for the big decision around what the future holds, Jeremy is still weighing up his options. Some potential interests include town planning and physiotherapy. "I'm still undecided on what direction I'll head in but I'm narrowing down areas that I'm interested in and talking to family friends who are working in those fields to get a real-world insight."

"I think the key to minimising stress is being organised, and good planning."

Chapter 4. DISORDERS OF LEARNING

Learning new or complex concepts can be difficult enough for anyone. But when you have a learning disability, it can be slow, demoralising or even impossible.

These learning disorders are not related to a person's intelligence or lack of education. They result from specific problems in processing information. Learning disorders are neurologically based, and can cause trouble with reading (dyslexia), writing (dysgraphia) or mathematics (dyscalculia). These disorders are distinct from problems in learning that arise from visual, auditory or motor impairments. Although signs of these disorders are most recognisable during schooling, learning disorders can go unrecognised in individuals as they continue learning and reach adulthood.



DYSLEXIA

This is a lifelong disorder that's estimated to occur in 5–10% of the population. A person with dyslexia has trouble decoding words quickly and accurately and may find comprehension and spelling difficult. Some report that the words seem to 'jump around' on the page as they read. Many have difficulty learning and recognising the sounds of letters.
Dyslexia tends to run in families, with research finding that the disorder has a strong genetic basis. Some studies have found that training in phonological awareness skills – recognising sounds and what they look like, rather than individual letters – can help dyslexic children improve their reading abilities.

DYSCALCULIA

Those with dyscalculia have difficulty learning maths and understanding numbers. Common symptoms include trouble comparing numbers, recognising symbols or telling the time from an analogue clock. Dyscalculia, unlike dyslexia, is not lifelong. One US study of students with dyscalculia found that the disorder persisted for longer than one school year in only 11% of participants.

DYSGRAPHIA

Dysgraphia is a problem with written expression leading to illegible handwriting, trouble spelling and spacing words, and difficulties putting thoughts on paper. People with the condition may write words incorrectly or in the wrong order.

ATTENTION DEFICIT HYPERACTIVITY DISORDER (ADHD)

ADHD is the most common neurodevelopmental disorder affecting children and teenagers. As of 2013,

it was estimated to affect 39 million people worldwide, three-quarters of whom are male. ADHD is not strictly considered a learning disorder. However, research shows that 20–25% of children with the condition have coexisting learning disabilities in reading, spelling or maths. Young children or teenagers with ADHD typically are hyperactive and have trouble paying attention and controlling their impulses. Researchers believe the condition results from a mix of genetic, environmental and neurological factors. Studies using magnetic resonance imaging (MRI) have identified several brain regions that differ in people with ADHD. These include the frontal lobe, which is important for executive functions such as planning and controlling attention, as well as regions involved in motor activity. ADHD appears to run in families. Close, or first-degree, relatives of people with ADHD are far more likely to also have the disorder, with the risk for siblings being two-to-three times as great as those of siblings without ADHD. The condition is treated with either, or both, behavioural therapy or specific drugs. There remains significant debate and controversy over both the diagnosis and management of ADHD, complicating studies on its effect on learning.

DID YOU KNOW?

As of 2013, ADHD was estimated to affect 39 million people worldwide, three-quarters of whom are male.

OTHER CONDITIONS AFFECTING LEARNING AND MEMORY

Many medical conditions affect the health of the brain and therefore its ability to learn. This includes conditions present before birth, genetic disorders, or diseases or injuries acquired throughout life. The effects can be temporary: concussion, for example, results when the brain knocks against the inside of the skull, causing short-term symptoms including memory loss and difficulty concentrating. Hearing or speech language impairments, particularly if unrecognised, may affect communication in the classroom. Other conditions, including Alzheimer's disease, affect the brain areas crucial to learning and cause irreversible damage.

PROFILE

CAN'T SPELL . . . BUT SHE SURE CAN WRITE!

SHE IS ONE OF AUSTRALIA'S MOST PROLIFIC AND HIGHLY AWARDED CHILDREN'S AUTHORS AND YET JACKIE FRENCH SUFFERS FROM A LEARNING DISORDER THAT MADE READING AND WRITING AN ORDEAL FOR HER WHEN SHE WAS GROWING UP.

Yes, the much-loved Australian author Jackie French suffers from the learning disorder dyslexia. And yet she's written more than 200 books, including best-sellers such as *Diary of a Wombat* and *Hitler's Daughter*. Her books have won more than 60 awards in Australia and internationally and sold millions of copies worldwide.

Jackie wrote her first children's book, *Rain Stones*, at the age of 30, more than 30 years ago, while living in a shed with Fred the wallaby, Gladys the black snake and Smudge the wombat. It's now part of Australian literary folklore that the manuscript for *Rain Stones* was described by editors at publisher HarperCollins as one the messiest and worst-spelled they'd ever received. Smudge, who left his droppings on the typewriter, was responsible for the mess. But the spelling was due to Jackie's dyslexia.

She recalls that her first memory of school was of sheer terror at having to read one word aloud at the request of her teacher. "To this day, I still find reading single words, and handwriting difficult, but I've learnt to adapt," she says. Fortunately her grade one teacher, Miss Davies, recognised Jackie's difficulties and, despite having 42 children in her class, taught every one, including Jackie, how to write… although Jackie acknowledges that her writing never became entirely legible. Miss Davies, Jackie recalls, recognised children's strengths instead of their challenges. As a result, rather than holding her back, dyslexia and a passion for problem-solving have been key to Jackie's success.

"Talent is two a dollar," she says. "Genius needs persistence. Dyslexics either become cowed by those who don't understand the way they need to see or learn, or become determined and creative problem-solvers. I love the music of words. I love collecting the data, analysing, substantiating and correlating until the data becomes a theory, theme or a story.

"What we need to teach kids, at a young age, is do whatever helps you get to where to want to go. Don't follow your dream – grab it and pull it along with you. Be realistic, be stubborn, be flexible, have the courage to find what you love doing, and then do it."

Jackie is now a patron for literacy programs across Australia and spends a lot of time with children who struggle with reading. "The first thing I tell them is: 'of course you can do it'. I have never known anyone who cannot read – even if it takes far longer or even complex technology to make it possible. Show kids how to find 'the magic book'– the one they love so much they will go to extraordinary lengths to find out what comes next."

PHOTOGRAPH KELLY STURGISS

Chapter 5. AGEING AND LEARNING

AGE PATTERNS

As we age, our ability to learn and remember changes. Due, for example, to 'infantile amnesia', most of us can't remember anything about being a toddler. We don't know why. The memories might still be there but not easily accessible. Or it could be that the circuits holding those earliest memories are overwritten when new brain cells are produced and integrated.

Around adolescence, our prefrontal cortex – which controls planning, decision-making and working memory – develops significantly. Our ability to plan for the future improves and we can process more information when deciding between different options.

Our ability to remember new information peaks in our 20s, and then starts to decline noticeably from our 50s or 60s. Because the hippocampus is one brain region that continues producing new neurons into adulthood, it plays an important role in memory and learning. The section called the dentate gyrus is where the new neurons are created. Many are produced during childhood, but activity in the dentate gyrus slows down as we age. The reason for memory decline isn't known but may involve this decreased rate of neurogenesis.

Dementia, which is experienced by 10% of people older than 65, occurs when abnormal proteins accumulate inside and around neurons. These proteins are thought to affect our memories by killing the synapses and ultimately the neurons that hold memories together.

Exercise and ageing

THERE'S NO escaping it: cognitive function declines with age. But it's not all bad news. An important key to slowing decline may lie in exercising not only the brain, but also the body.

QBI's Professor Perry Bartlett was one of the first people to discover that the adult brain contains stem cells capable of making new neurons. As the brain ages, these stem cells lose their ability to produce new neurons, causing cognitive function to decline.

Ground-breaking research by Prof Bartlett and Dr Daniel Blackmore recently identified that exercise is able to increase production of new brain cells and improve learning and memory. They are now heading up a clinical trial monitoring 300 people aged 65 and older to identify the right amount, intensity and type of exercise that leads to cognitive improvement in the ageing brain. "This will be the most comprehensive analysis yet of why exercise is beneficial," Prof Bartlett explains. "Ultimately, we would hope to have clear public health guidelines as to how exercise can both prevent and reverse dementia."

A key to *SLOWING DECLINE* may lie in exercising not only the brain, but also the body.

PROFILE

A LEARNING BREAKTHROUGH

IT USED TO BE THOUGHT THAT THE ADULT BRAIN WAS HARDWIRED: WHAT WE HAD BY A CERTAIN AGE WAS AS GOOD AS IT GOT. BUT QBI'S **PROFESSOR PERRY BARTLETT** TURNED THAT THINKING ON ITS HEAD.

"When I started researching the brain in the late 1970s, the general dogma was that the adult brain was fixed and unable to change," Professor Perry Bartlett explains. "It was very exciting when I was able to prove that there were actually stem cells in the adult brain, which means that the adult brain has the capacity to repair itself." The discovery clearly has significant implications for treating people with brain injuries and diseases.

In 1982, Prof Bartlett first predicted the presence of stem cells in the brain. A decade later, he proved the theory when he found them first in the brains of mouse embryos and then adult mice. In 2001 he became the first person to isolate these cells in adult mice.

His research progressed to focus on stem cells in the hippocampus. "We know the hippocampus is vital for the formation of spatial navigation and remembering when and where activities occur," Prof Bartlett says. "Our latest work suggests that many different groups of stem cells are at work in the hippocampus, regenerating new neural connections. We now understand that the brain is very plastic, changing all the time."

Recently, Prof Bartlett successfully used exercise to improve cognition in older mice. He is now leading a human clinical trial to determine the amount, intensity, and type of exercise that leads to cognitive improvement in the brains of elderly people (see p20). "The effect of dementia on hundreds of thousands of Australians is debilitating and devastating," he says. "If we can show that exercise can actually slow down or reverse the onset of dementia, then we can potentially make a positive difference to a lot of people's lives.

"Our first thought back at the beginning was, 'Wow, now we will be able to repair the brain', and, while it's still a long road, researchers are now well on the way to doing that. What excites me is that our initial discoveries nearly 25 years ago are now leading to potential treatments for dementia, and maybe for depression too."

DID YOU KNOW?

Prof Bartlett was founding director of QBI, which he established in 2003, with 10 researchers.

In 2015, he became just the ninth recipient of the CSL Florey Medal for his breakthrough discoveries in neuroscience. This medal is one of Australia's most prestigious scientific awards and recognises a recipient's significant achievements in biomedical science and/or human health advancement.

In 2017, in recognition of his career, Prof Bartlett was named a Queensland Great, and the Queensland Senior Australian of the Year.

PHOTOGRAPH RICHARDS BRIGGS /FAIRFAX SYNDICATION

BRAIN TRAINING

THERE ARE NOW COUNTLESS ONLINE APPS AND SOFTWARE PROGRAMS THAT ENCOURAGE PEOPLE TO EXERCISE THEIR BRAIN TO BOOST COGNITIVE FUNCTION. DOES 'BRAIN TRAINING' REALLY WORK?

"There's no doubt that repeatedly doing certain tasks improves performance on those tasks," says Professor Jason Mattingley, a cognitive neuroscientist at UQ's QBI and School of Psychology. "It's been much more difficult to prove any broader benefits for brain function, or help with untrained tasks."

Prof Mattingley and his team have now shown that brain training for specific tasks can also improve broader brain performance, when combined with brain stimulation. They recently studied the benefits of brain stimulation devices that deliver transcranial direct current stimulation (tDCS) via electrodes on the scalp (see image above). In the study, participants were trained in a simple decision-making task while they received either active or sham (placebo) brain stimulation. The team then used mathematical modelling to quantify any improved performance. Participants were later re-tested, on both the trained task as well as a visual search task for which they'd received no training.

The researchers found that after four sessions of training, combined with tDCS designed to increase activity in the brain's left prefrontal cortex, participants' performance in both the decision-making task and the untrained visual task improved.

"This study is the first to show transfer of performance benefits to untrained cognitive operations with these types of tasks," Prof Mattingley says. "What's more, these generalised benefits were still evident a fortnight later."

He believes the study's outcomes support an important new research direction into the neural basis of cognitive training. "Our findings could help in efforts to stop cognitive decline associated with healthy ageing, or improve cognition in people with brain disease or injury," Prof Mattingley says. He cautions, however, about the use of DIY brain stimulation. "There are still many unknowns with these technologies. Although brain stimulation devices are now available commercially, we would not recommend people embark on do-it-yourself brain stimulation at home."

DID YOU KNOW?

PHOTOGRAPH PATRICK HAMILTON

Professor Jason Mattingley
COGNITIVE NEUROSCIENTIST AT UQ'S QBI AND SCHOOL OF PSYCHOLOGY.

Prof Mattingley's research also investigates selective attention, the process by which we filter out information to focus on certain objects – a topic that fascinates him. "Most of us regulate our attention effortlessly, and for the most part we're not even aware of what we're doing," he says. "But attention is a multi-faceted and complex brain function that is only beginning to be understood. It's important we do so, because many developmental and acquired brain disorders cause impairments of attention, and these can be very debilitating for sufferers."

PROFILE

USING AND KEEPING A HEALTHY MIND

DR SALLYANNE ATKINSON AO IS CONVINCED THAT STAYING PHYSICALLY AND MENTALLY ACTIVE IS KEEPING HER CAREER SHINING, WELL INTO HER EIGHTH DECADE.

At the height of Dr Sallyanne Atkinson's political career, she became renowned for her quick wit and astute intellect. Now, as she approaches 75, she believes it's more than just good luck and fortunate genes that continue to keep her mind as sharp as ever.

She strongly believes there's truth to the adage *use it or lose it* and continues to remain both mentally and physically active as she forges through her 70s. Sallyanne walks every day, plays tennis weekly and remains passionate about the arts in various forms.

She has long been interested in how the brain works and learns. Throughout her high-profile career, the former — and still only — female Lord Mayor of Brisbane has blazed a trail as a journalist, political and business leader, and working mother. Now as the current Chair of the Queensland Brain Institute's advisory board, Sallyanne is committed to the exploration of the science that underpins learning. "Once the research community understands how people learn, or how people don't learn, that has huge implications not just for the education of children, but for people in the workplace," she says.

"How people learn is more significant than what they learn"

As a strong advocate for lifelong learning, Sallyanne is also a patron of the University of the Third Age, an international body that promotes learning for personal enjoyment and satisfaction, particularly in people beyond retirement age. "You've got doctors doing ancient history and people who never went to university, but have been readers their whole lives, studying English literature," Sallyanne explains. She recalls one woman aged in her 90s who was teaching Latin: "She was so good at it that her classes were always booked out."

Sallyanne says she has a "low threshold for boredom" and enjoys variety, which is reflected in the breadth of her professional interests. In addition to her QBI commitments, she is Chair of the Museum of Brisbane and President of Women's College within The University of Queensland, among many other high-level professional engagements.

Sallyanne believes that different pursuits stimulate the brain in different ways, and that understanding the underlying mechanisms is enormously important. "How people learn is more significant than what they learn," she says. "I think QBI research is about [understanding] the how."

Read more about Sallyanne in her memoir, No Job For A Woman, *available at uqp.com.au or at all good bookshops.*

PHOTOGRAPH JUSTINE WALPOLE

THE SCIENCE OF LEARNING

A need for evidence

It's now widely accepted that to improve learning outcomes, teachers need solid evidence to support what they put in place in the classroom. This need for accessible research into what really works in schools and classrooms is known as the 'science of learning': a relatively new field that brings together researchers from disparate areas.

In Australia, the field is led by the Science of Learning Research Centre (SLRC), a national collaboration between nine research organisations and the State Education departments of Queensland, Victoria and South Australia. Headquartered at The University of Queensland, the SLRC aims to bring together researchers from the disciplines of neuroscience, cognitive psychology and education to develop scientifically validated strategies.

Incorporating the three disciplines is a complementary approach, explains Professor Pankaj Sah, Director of both the SLRC and QBI. "Neuroscientists have long been interested in learning and memory formation. How is it that the brain learns? How do you lay down memories?"

Likewise, Prof Sah says, psychology researchers are interested in the behavioural side of learning: how we interact with each other, perceive our environment, and react to certain stimuli. "And education researchers and teachers," he adds, "are of course interested in the practical processes of learning and teaching."

The SLRC has experimental classrooms in Brisbane and Melbourne in which new learning principles are tested. Findings from these are now guiding how teachers focus student attention to optimise learning.

Several science of learning centres are conducting similar research in other countries and the Australian SLRC is partnering with organisations and collaborators internationally. This includes the Neuro-Education Initiative at the Johns Hopkins School of Education in Maryland, in the US.

NAPLAN IMPROVEMENT

The SLRC has trained more than 1200 teachers, including in a numeracy intervention program in the Port Augusta–Quorn region of South Australia. In collaboration with the South Australian Department of Education and Child Development, researchers worked closely with teachers to reduce student anxiety about maths, leading to improved NAPLAN scores in the region.

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