If you thought that memory was all about making a record of the past, think again, says **Jessica Marshall**

Future recall

IMAGINE your next vacation. You are relaxing on a beach, waves lapping at the shore, a cool breeze wafting through the trees and the sun caressing your skin. Fill in the details. What else do you see? Now, remember yesterday's commute. Again, a picture emerges. You are on the train or in your car, or maybe just wandering from your kitchen to your desk. Can you remember what you were wearing? Perhaps you have forgotten that part already.

Without breaking sweat, you can hurtle yourself backwards or forwards in time in your mind's eye – what is known as "mental time travel". One of these visions really happened and the other was fantasy, yet the act of conjuring them up probably felt very similar. It's as if, embedded somewhere in your brain, there is a time machine that can take you forwards and backwards at will.

Neuroscientists and psychologists are starting to think so, too. After more than a century of focusing on just one aspect of mental time travel – remembering the past – these scientists are turning their minds to a bigger question: what if we have been looking at only half the picture? What if the thing we call "memory" works both ways, helping us both recall the past and imagine the future?

The idea makes intuitive sense. When you imagine yourself on a beach, you draw on your experiences of past trips to the ocean, conjuring up a familiar scene and then filling in the details. Maybe memory provides the

raw materials for these sorts of jaunts.

The idea increasingly makes scientific sense, too. Evidence is accumulating of an intimate mental connection between recalling the past and imagining the future. Neuroscientists and psychologists have found that people who have lost their memories also lose their ability to imagine the future, and that the brain regions that are used for remembering are also used for imagining. These similarities may help explain some of our memory's weaknesses, and even suggest that we are built to spend much of our lives engaged in mental time travel.

It was the ancient Greeks who first proposed that memory plays a key role in envisaging the future. In modern times, the first inkling of a link between our pasts and futures came from a celebrated patient known as K.C., who lost his memory in 1981 after suffering brain damage in an accident. Among other things, K.C. helped researchers discover that we have several different types of long-term memory, which can be broadly broken down into three categories: semantic (knowledge of facts), episodic (memories of events in our lives) and procedural (knowing how to do something like ride a bicycle).

Can't picture it

K.C. has a specific problem with his episodic memory: he knows plenty of facts but is unable to remember anything about his personal past. Researchers noticed in passing that something else was wrong. "He could not think about his personal future," says neuroscientist Endel Tulving of the University of Toronto in Canada, who studied K.C. for more than 20 years.

Other researchers soon began to stumble across links between memory and future thought. Another patient, D.B., whose episodic memory was wiped out after a heart attack starved his brain of oxygen, had similar problems to K.C. He knew where he worked and what sort of company it was, but he could not remember a single occasion of having been at work. Likewise, he could understand abstract concepts about the future – that global warming would be a significant ▶

TIM ASHTON

problem, for example – but he could not imagine anything about his personal future.

Other studies have found that suicidally depressed people experience a reduced amount of detail in their memories of the past, and an equivalent lack of detail about their imagined future. What's more, patients with brain damage that causes them to invent wild tales about their past tend to do the same about their futures. There is also the observation that children develop the ability to speak reliably about their past and their future at the same time, around 4 years of age, a long time after they are able to articulate accurate information about the world. And, just as our memories fade with age, so does our ability to imagine our future.

"The patient knew what he did and where he worked, but could not recall ever actually being there"

Although researchers have been making these observations for more than a decade, it is only in the past couple of years that they have started to systematically probe the link between recalling the past and imagining the future. "I've always been intrigued by it, but couldn't find a way to study it," says psychologist Daniel Schacter of Harvard University, who has also worked with K.C.

That has now changed. Last year, a team led by Eleanor Maguire of University College London recruited five amnesic patients with brain damage, and asked them to imagine a future episode, such as a visit to a new museum or a meeting with a friend, and describe it in as much detail as possible. They found that although the amnesic patients could conjure up fragments of the future, their scenarios were much less detailed and concrete than those of control subjects (*Proceedings of the National Academy of Sciences,* vol 104, p 1726). "They couldn't form a strong mental picture," says team member Demis Hassabis. As one patient put it: "It's not very real. It's just not happening... I'm not picturing anything at the moment."

One obvious interpretation of this is that the brain regions that underpin episodic memory are also involved in episodic future thought. Brain-damaged patients, however, are not especially useful for confirming that idea: it is hard to rule out the possibility that the damaged region is necessary for both tasks but other, distinct brain regions are

TIM ASHTON

involved as well. Fortunately, there is a way to answer the question.

Researchers have recently started using techniques such as functional magnetic resonance imaging (fMRI) to watch the brain activity of people with fully functioning memories as they remember the past and imagine the future. These studies show something striking and unexpected: as far as the brain is concerned, there is very little difference between the two.

In one such experiment, a team led by Kathleen McDermott of Washington University in St Louis, Missouri, recorded activity as subjects either recalled or imagined a common experience, such as a birthday party, a barbecue or getting lost. McDermott's team expected to see different patterns of brain activity associated with the past and the future – but they didn't. Both tasks produced very similar patterns of activity, with some regions of the brain more activated by future imaginings. Intriguingly, there was no region that lit up only when remembering the past. "We really thought we were going to see a region that was more active in memory than in future thought," says team member Karl Szpunar. "We didn't find that." In other words, episodic memory does not appear to have a specialised brain module dedicated to it, but is handled by part of a universal module for mental time travel (*Proceedings of the National Academy of Sciences,* vol 104, p 642).

False memories

In a similar experiment, Schacter watched brain activity unfold as subjects recalled a memory or imagined a future scenario and then elaborated on it. He suspected that separating these two stages of the process might help tease apart the similarities and differences between mental past and future.

Similar to McDermott, Schacter found that imagining the future activated the same brain regions as recalling the past, plus a few others, but these differences were restricted to the initial construction phase – placing yourself on the beach. Elaborating on the scenes – adding the trees, the ice-cool drink, the lapping waves – showed almost identical activity, whether for past or future. "It's almost as if you're doing the same sort of thing," Schacter says. Intriguingly, the brain regions engaged during the elaboration phase, both past and future, were already well known to memory researchers. They call it the "autobiographical memory network" (*Neuropsychologia*, vol 45, p 1363) – more evidence that the brain uses memories as raw material for constructing possible futures.

> "I cannot imagine how civilisation could emerge from brains that cannot imagine the future"

All of this suggests that our personal past and future are tightly linked in the brain. Projecting the future may not be the major function of memory, but it certainly is one of its primary functions, Schacter says.

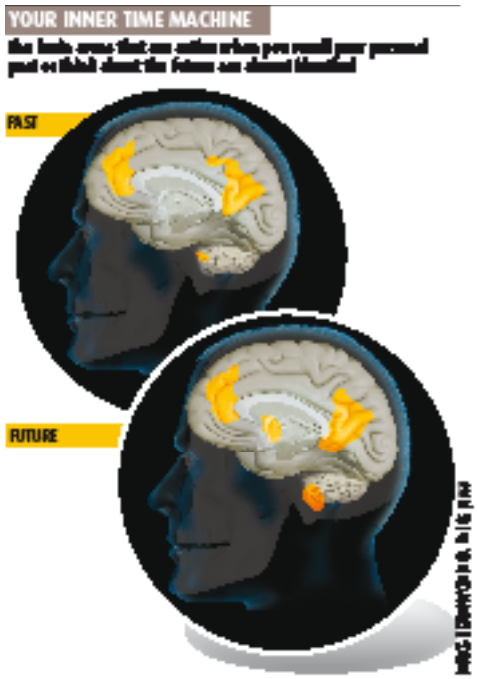
This makes sense from an evolutionary perspective, Tulving points out. It is hard to imagine how personal recall alone might be evolutionarily useful, but if remembering how cold and hungry you were last winter helps you realise the benefits of putting food away for the next one, or convinces you to plant a few of your grains instead of eating them all, you stand a much better chance of surviving than someone who cannot project themselves backwards and forward in time. "I cannot imagine how civilisation could emerge from brains that cannot imagine the future," Tulving says.

The tight link between our past and future also sheds light on some long-standing mysteries about memory. If our capacity to remember evolved to help us imagine and shape our future, the way our memories work should reflect that function, Schacter says – and indeed it does. Our memories are not flawless action replays of what actually happened: chances are you do not remember what you were wearing the day before yesterday, or which cup you drank your coffee from. Yet, if you were pressed to provide details, you would almost certainly come up with something.

This seems to be how episodic memory works in general. We remember bits and pieces of our experiences and then reconstruct them to create plausible, but not necessarily accurate, accounts of what happened. Such structures makes sense, say Schacter and others, if one of the main functions of memory is to shuffle scraps of the past around in novel ways to project possible futures.

This "constructive" nature of memory helps explain some puzzling flaws in our memories, particularly the ease with which we form false memories. To illustrate this, Schacter points to the investigation into the 1995 Oklahoma City bombing. Detectives initially looked for two suspects because a mechanic at the body shop where bomber Timothy McVeigh rented the van used in the attack was sure McVeigh had come in with another man. In fact, the alleged accomplice had been to the shop the day before, accompanying a man who looked similar to McVeigh. Two real episodes had merged in the mechanic's mind to create an inaccurate memory – and a false lead for the authorities.

This type of fallibility can be easily demonstrated in lab studies. People shown ▶



Your fallible memory

Read this list of words, wait a few minutes, and then turn over the page

tired bed awake rest dream night blanket doze slumber snore pillow peace yawn drowsy

CATEGORIES OF REMEMBERING

a list of words such as "tired", "bed", "dream", "doze" and "pillow" can be easily tricked into remembering that the word "sleep" appeared on the list too, even if it did not. They do not make the same mistake with unrelated words – for instance, "butter" (see "Your fallible memory", page 39). This, says Schacter, is a good demonstration of the constructive nature of our memory. We recall the gist but not exhaustive detail.

Paradoxically, amnesic patients and people with Alzheimer's disease often perform better in this kind of test than people with fully functioning memories. This fact seems puzzling – why would somebody with a damaged memory perform better on certain memory tests? But if our memories are designed to remember the outline of things and fill in the rest, this "failure" makes sense. False memories are not memory deficits at all but by-products of a normal, healthy memory, Schacter suggests.

These links have got researchers excited, and are prompting further questions. One of these is how the brain handles the time dimension of remembering and imagining. We have no problems distinguishing memories from future scenarios, and we can also form memories of our imaginings – remembering today that yesterday we were thinking about next year's vacation, for example. There is strong overlap in the brain regions involved, yet there must be something different about them. What is it?

Tulving thinks of mental time travel as having two components: the content of the event itself, and the shifting of the event in time. He is working out how to tease these apart experimentally, and hopes to find parts of the brain that are responsible for carrying our events back and forth in time.

Vivid imagination

Another key question concerns individual differences in memory and imagination. We're familiar with the idea that some people have better memories than others. Might the same be true of imagination? And might people with a richer stock of memories be more imaginitive when it comes to thinking about the future? "There might be a paradoxical answer," says psychologist Daniel Gilbert, a colleague of Schacter's at Harvard. Perhaps people with good memories have less vivid imaginations, and vice versa. He and Schacter plan to test that hypothesis.

These questions aside, the intimate link between our inner past and future now looks pretty secure. Buy do we really plan for the future in this way, by dreaming up scenarios with ourselves as the main character? "Yes, we do, though I think it's under-studied," says Schacter. "There's work that suggests a significant portion of mental life is spent thinking about the future."

Much of that work has been documented by Gilbert in his book *Stumbling on Happiness*. "Every time you say, 'I think I'll go have lunch', you've just thought about the future," he says. That is just one small example of a general tendency to project ourselves forwards in time. According to Gilbert, psychologists studying stream of consciousness have found that the average person reports spending about 12 per cent of their waking hours thinking about the future.

It is easy to see the benefits of spending so much time in reverie. Running through future scenarios helps us achieve outcomes we want – and avoid ones we do not, perhaps as a direct result of learning from memories of past mistakes. We can maximise the enjoyment of future events by looking forward to them, while envisioning negative events helps us minimise their impact: volunteers' hearts beat faster and they sweat more over lesser, but unpredictable, electric shocks than over larger, predictable ones.

In fact, there is evidence that mental time travel is such an important part of our inner lives that our brain will engage in it whenever it gets the chance. For more than 50 years, neuroscientists have known that even when your brain is apparently at rest, there is something important going on inside it. This comes from experiments showing that as the brain shifts gear from a passive, undirected state to an active, directed one – such as solving a puzzle – overall blood flow and oxygen uptake stay the same. So the "default" brain is up to something – but what?

A number of recent studies have tried to answer this, by scanning subjects who are doing nothing in particular. These studies always find the same surprising pattern of brain activity: the brain's default state shows remarkable overlap with the mental time-travel network discovered in recent brain scans, according to Randy Buckner, another Harvard psychologist (*Trends in Cognitive Sciences*, vol 11, p 49). It seems that unless called upon to do something specific, your brain is busy recalling the past or projecting into the future. So next time you catch yourself staring into space instead of getting on with your work, or drifting into reverie as you try to read a book, don't beat yourself up about it. Your daydreams will pay off in the long run. ●

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Your fallible memory, Part 2

Which of these words appeared in the list on the previous spread?
blanket butter snooze house