frontiers FOR YOUNG MINDS

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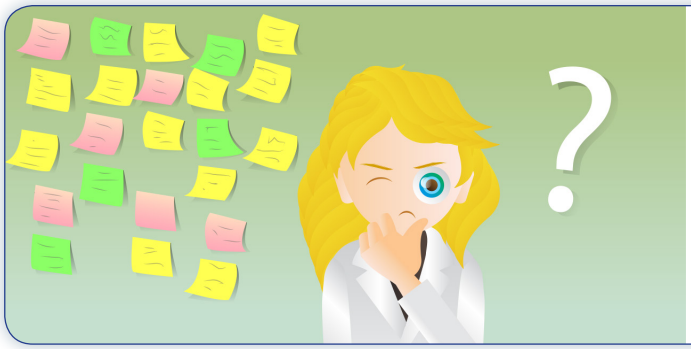

Thanks for the memories ...

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Reviewed by:

Lilly
11 years old

Everyone wants a good memory but we do not often ask ourselves what memory is for. Let us begin our exploration of why memory is important and how it works with a little memory test: Do you remember what you learned in class last Wednesday? How about what you got for your last birthday? One of the greatest mysteries of the human mind is why we remember some things, but not others. Why is it that we might have perfectly vivid memories of what we did on vacation 2 years ago, yet we struggle to remember details from what we learned in class just last week? What happens in our brain that turns some moments into lifetime memories, while others are lost, forever forgotten?

HOW DOES MEMORY WORK?

It turns out that there is one brain structure that appears to be a 'memory maker'. Without it, we cannot remember anything that has happened to us, even from only a few minutes ago, let alone from last summer. Indeed, there was a very famous case of a patient named Henry Molaison (often referred to as H.M.), who had damage to his brain and was completely unable to form new memories. This kind of conditions, in which a person cannot make new memories, is called **anterograde amnesia**. The brain structure that is needed to form these kinds of memories, and which was damaged in Henry's brain, is the **hippocampus**, a seahorse shaped brain region buried deep inside your head between your ears, as shown in the Figure 1.

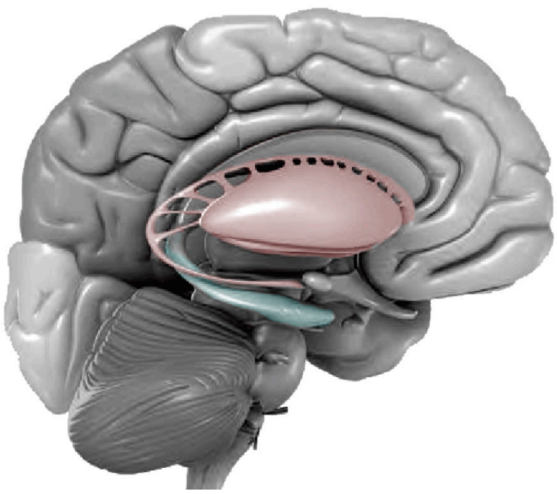

FIGURE 1 - Different parts of the brain support memory in different ways. The hippocampus (shown in teal) creates vivid memories of episodes or events. The striatum (shown in pink) learns from experience to form habits. Both kinds of memory are shaped by the importance and relevance of events, so that we can be better at finding the good things and avoiding the bad things that surround us.

Perhaps what is even more amazing is that patients like Henry can lose their ability to create new

memories, yet they are still perfectly capable of bringing to mind old memories. Moreover, Henry could hold a conversation, do math, maintain friendships and do almost everything normally … except build new memories. This is because other aspects of the way we perceive and think about the world remain intact after the hippocampus is damaged.

But other than the rare patients with specific damage to the hippocampus, how do we study how memories are formed in a healthy brain? In the lab, we can study how memories form in a person's brain by using functional magnetic brain imaging (or fMRI for short). This tool allows us to measure which brain regions are most active during new learning.

We bring in healthy volunteers and ask them to play a "computer game" that tests their memory. The game is pretty easy from the perspective of the participant. They come in to the lab and we put them in the fMRI scanner while they are able to view visual images on a computer screen – much like watching a movie (sometimes we do show movies!). While they are watching images on the screen, we take pictures of their brains every few seconds. This gives us a changing measure of activity in the whole brain. Then, we take them out of the scanner and they go home. The next day, they come back to the lab and we test their memory for the previous day's experiences. Once we know what each person remembered or did not remember, we are halfway there: now we can see if there was something special that happened in the brain the day before for things that people remembered. We do this by sorting brain activity from the first day into two piles – brain activity that happened when people later remembered the event and brain activity that happened when people later forgot the event. When we do this, we are able to clearly see that the hippocampus is much more active when people are forming memories! We can also put people in the fMRI scanner during the memory test, and we see that the hippocampus is again more active when people are remembering more details. Altogether, then, by simply showing people new things and getting them to form new memories in the laboratory, we can peer into the brain to learn about how it remembers.

WHY DO WE REMEMBER SOME THINGS BETTER THAN OTHERS?

You might be wondering: if we all have a hippocampus whose job it is to help us build new memories, then why do we forget so many things? Of course, we cannot remember everything (and we probably would not want to!). Indeed, an important difference between our brain's memory and a computer's memory is that our brains filter our experiences. Some experiences turn into lasting memories, others decay over time and are forgotten, making room for new ones.

One interesting aspect of this process is that which memories stay and which are forgotten is not random. Our brain has several ways of making sure that the memories it holds on to are the particularly important ones to each of us: things that are essential for survival, such as food (have you ever forgotten which cupboard the cookies are in?) or things that we care about or enjoy, such as everyday events related to our family, friends, and interests.

One way that the brain makes sure to remember the events that are important to us is through specialized chemicals called **neurotransmitters**, which, when released, help build stronger memories. One such neurotransmitter is **dopamine**. Dopamine is released in the brain when something surprisingly good happens, such as walking into class and finding a box of chocolates on your desk. When dopamine is released, it strengthens memories. It does so by *tagging* these memories when they are created in a

way that makes these memories slowly strengthen over time. This means that just as memories for unimportant things start fading away, memories for important things grow stronger over time. In the end, memories for these surprisingly good events can have greater influence over our behavior, making it easier to use these memories to get the things we really want or need.

A similar process takes place when especially bad things happen, such as eating something that tastes terrible, encountering a spider, or other frightening events. This kind of *fear learning* depends on a specialized part of the brain, the **amygdala**, which works together with the hippocampus to strengthen memories. As with good events, it is easy to understand why we would need to have strong memories for bad things that happen to us. After all, an important part of survival is learning how to find the chocolates and avoid the spiders.

IF WE DO NOT REMEMBER WHAT HAPPENED, HOW CAN WE STILL REMEMBER WHAT TO DO?

So far, we have discussed vivid memories for specific events or episodes, a kind of memory sometimes referred to as **episodic memory**. But past experiences – whether good or bad – can shape our behavior even when we do not have a vivid memory of the experiences themselves. This kind of unconscious influence of past experiences on behavior is often referred to as **habit learning**, and it exerts a greater influence on our behavior than most of us realize (and maybe greater than we would like). Have you ever reached for a cookie, only to realize that you probably should have had an apple, or found yourself playing a video game for hours when you meant to do your homework? These are just two examples of how habits – whether we like it or not – can shape our behavior.

Whereas episodic memory depends on the hippocampus, habit learning depends on a different part of the brain – the **striatum**, shown in the figure below. But similar to episodic memories, specific habits are not formed randomly. They are shaped by the outcomes of our actions and are strengthened with dopamine. You already know that when we encounter unexpectedly good outcomes, our brain releases dopamine. In addition to strengthening memories in the hippocampus, dopamine also strengthens habit learning in the striatum. Except that, in the striatum, dopamine reinforces memories for actions, instead of for episodes. This way, when something good happens, it not only strengthens memory for what happened, but also reinforces the action that led to it. If a particular action (e.g., opening the cookie box) repeatedly leads to a good outcome (enjoying the cookie), the repeated reinforcement biases our brain to take that same action again next time, even if we have no conscious memory of these events at all. This is why, sometimes, we do not remember what happened, but we remember what to do. Habit learning promotes behaviors that have been successful in the past. Moreover, behaviors that are habitual can happen quickly and automatically, so that they can adaptively guide our behavior even when we are distracted, stressed, or tired. This may be useless on an exam, but it is crucial for survival.

At the beginning of this article, we asked you to remember two things. Our guess is that most of you were probably able to remember what you got on your last birthday but struggled to remember what you learned in class last Wednesday. If you want to tip the balance ever so slightly and remember more of what you are learning in school, we put together a few suggestions (see Box 1). In the end, if you can find a way to turn everyday moments into something more personally relevant, more meaningful, and pair it with reward (did you say chocolate?) – you are helping your brain work for you!

Psychologists have spent over a 100 years trying to figure out how we can improve our memory, but the practice of improving our memory dates as far back as ancient Greece. The story goes that the art of 'mnemonics' (meaning anything that improves memory) was cultivated by the need to remember and recite speeches and poetry to the community. Instead of reading a written speech (or, rather, one downloaded to your iPad!), ancient poets had to memorize their poems. Out of necessity, they came up with clever tools. Perhaps one of the most famous tools is called 'the memory palace' – now who would not want one of those? The 'memory palace' technique is a way of using mental imagery to enhance memory. The way it works is that you first imagine any physical space you know really well, for example, your house. Then, you 'place' or imagine the things you want to remember (for example, all the things you need to pack for summer camp) in a separate room in your house, or memory palace. You might first imagine your bug spray on the couch, spurting out all over the pillows, then your bathing suit in the refrigerator (brrrr), and finally your sandals floating in the bathtub full of water. Then, when it comes time to pack up your bag, you simply 'walk' through your house and all of the items on your summer camp list should be waiting for you in your memory, in each room.

BOX 1 - Practical tips: how can we remember more?

GLOSSARY

Amygdala: An almond shaped group of brain cells located in the medial temporal lobe.

Anterograde amnesia: A loss of the ability to create new memories.

Dopamine: A neurotransmitter in the catecholamine family that plays a number of important roles in the brain and body.

Episodic Memory: Memory of time, places, and other autobiographical events that can be explicitly stated.

Habit Learning: Learned routines of behaviors that are repeated regularly and tend to occur unconsciously.

Hippocampus: A brain structure that is a component of the limbic system and is located in the medial temporal lobe.

Neurotransmitters: Chemicals that transmit signals from one brain cell to another.

Striatum: A subcortical part of the forebrain, and the major input of the basal ganglia.

FURTHER READING

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More information about the story of patient H.M., including pictures of his brain. Available from: http://thebrainobservatory.ucsd.edu/hm

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REVIEWED BY:

Lilly, 11 years old

I am 11 years old and I love gymnastics. I like science because it teaches me things that I am curious about. I like traveling and seeing new places. I play the viola and piano and I sing in two choirs. My grandpa is a scientist so I think I got his genes for science!

AUTHORS

Lila Davachi

I think it is amazing how we can use our mind to transcend time – we can imagine yesterday and tomorrow and we do this by using memory. Our memories are not just for remembering but they also change the way we see, think, and experience the world. I have been studying memory for longer than I can remember (insert laugh here) – and I am trying to understand how memories form, what the brain does, and how other things like emotion, rest, and sleep can change memory.

Daphna Shohamy

I am a professor at Columbia University, in New York City. In my research, I try to understand how our brain earns and remembers, and how it uses what we learn to change the way we behave. I have always been curious about why people behave the way they do, and even as a kid was intrigued by the idea that our behaviors have a biological basis. Learning, in the broadest sense, is a big part of this, because it is the way in which our brains, and our behaviors, change with experience – from the classroom, to our feelings and our friendships.