frontiers FOR YOUNG MINDS

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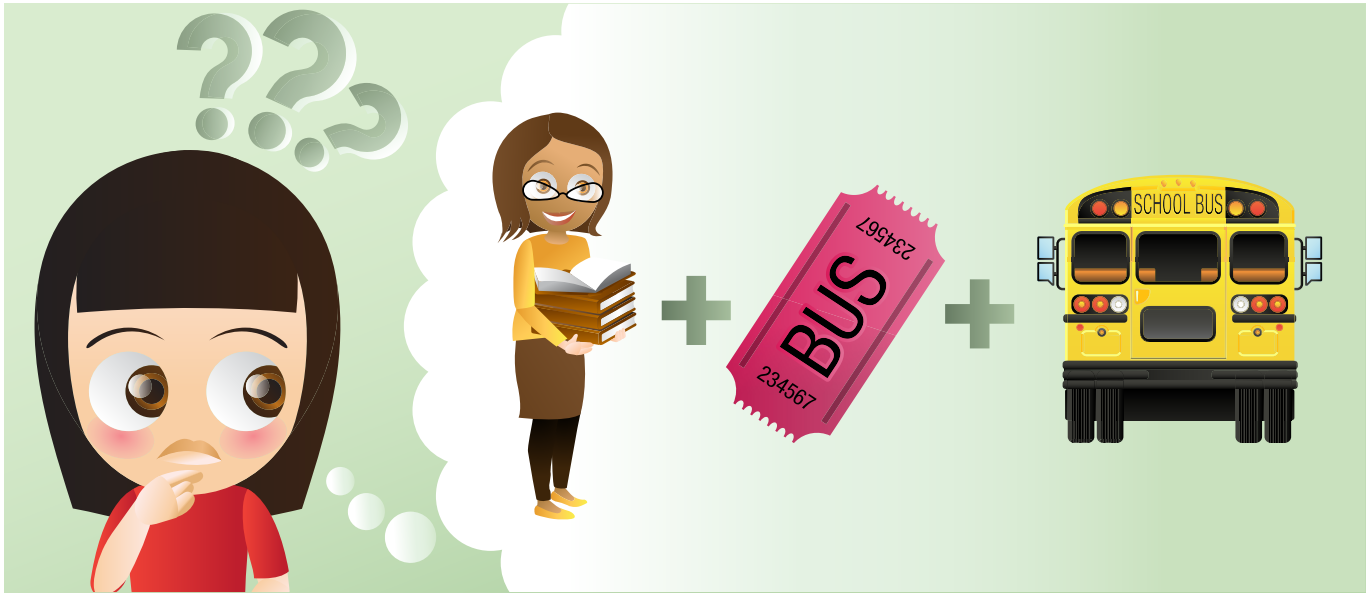

WHEN ONE IS MORE THAN TWO: INCREASING OUR MEMORY

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9–10 YEARS OLD

In our daily lives, we learn new things all the time. Unfortunately, it is usually difficult for us to remember everything that we learn. To increase our ability to remember, either for a few seconds or for many years, we can think in a way that ties together several pieces of information, so that they make fewer pieces of information. There are two ways the brain does this. One is called "chunking" and it is a way of thinking that allows us to keep more information in our memory for very short time periods. The prefrontal cortex is the part of the brain that helps us with chunking. When we need to remember information for a long time, a different part of our brain, called the perirhinal cortex, performs a similar process called "unitization," which links two or more items together through some sort of relationship between them. These ways of learning can help us when we need to remember lots of information, such as when we are studying for our exams!

We usually think that more is better: we want to have more money, to eat more French fries, or to know more so we will perform better on tests at school. When it comes to memory, however, when we have many things to remember, we can sometimes try to remember more than our memory

will hold or will bring back to mind. But what if we could help our memory so we could remember more? Trying to remember many little pieces of information is difficult. Scientists have shown us that if we join together many pieces of information, so that they make one piece of information, we can remember better. Joining, tying, or linking information together in our brain is called **binding**. We are going to tell you how to use two different types of binding to make your memory better, and we will also tell you about some of the things that scientists have discovered about memory and the brain.

BINDING/BIND

Joining, tying, or linking information together, so there are not as many little pieces of information. Two examples of binding are chunking and unitization.

GIVING OUR WORKING MEMORY A WORKOUT

When scientists talk about **working memory**, they mean a kind of memory that works to keep things in our minds for only a very short time, like a few seconds; you only need to hold that information until you deal with the situation or problem, then you can forget it. Unless we do something to keep the information in mind, such as saying it out-loud over-and-over again, it will quickly be forgotten. A reason information in working memory is lost so quickly, is that working memory can only hold a small amount of information, about seven items at a time. Information cannot stay in working memory forever. Things either need to be forgotten or moved out of working memory to more permanent memory, so that there is space for the new information that comes along.

WORKING MEMORY

A kind of memory that keeps things in our mind for only a very short time, like a few seconds.

Now imagine that you have been given a gift card to your favorite store and you want to use it on-line to buy something you really want. When it is time to check-out, you need to read the long number from the gift card, and then type it into the shop's website. In other words, you need to hold the gift card's number in your working memory. Let us say that the number is 977429112005 – that is quite a lot of digits! It will be very hard to keep such a long number in your mind, even for a few seconds. What if you realize that instead of remembering each digit separately, the number can be divided into several parts? This means you can use a memory trick known as **chunking**. It is called chunking because the information is divided into several sections, or "chunks," such as 97-742-911-2005, and each chunk could mean something special to you. For example, you might have gotten a 97 on recent science test, 742 might be the highway number closest to your city, 911 is the emergency telephone number, and 2005 is the year you were born. Now, instead of memorizing all these digits at once, you can simply memorize science-highway-emergency-born. Would not that be much easier? By using chunking, you have made more space in your working memory because all of those numbers only take up 4 spaces instead of 12. Good for you! You can also use chunking for other things such as if your friend asks you to get a book out of her locker and bring it to her. Your friend will quickly give you the locker combination, and you only need that number until you get to the locker and then you can forget it. What other things do you think you could use chunking for in order to remember them for a short time?

CHUNKING

A memory trick of grouping several things together into small groups in working memory. It is supported by the prefrontal cortex area of the brain.

PREFRONTAL CORTEX

A part of the brain located in the front of the head, above the eyes, and behind the forehead. It is used when we do the kind of thinking and planning that enhances our working memory, such as chunking.

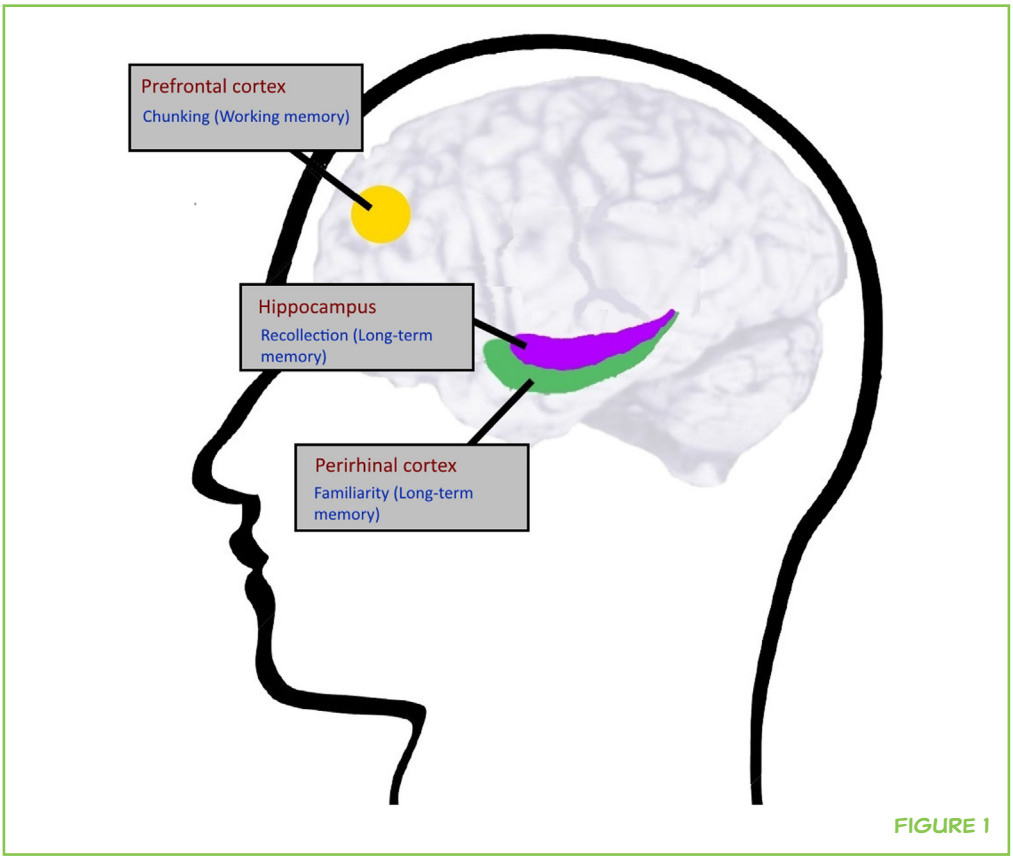
Scientists have discovered that whenever we use our working memory we use a brain area called the **prefrontal cortex**. This is the front part of your brain above your eyes and behind your forehead. You can see where this section of your brain is in Figure 1.

Scientists were curious about the way that the prefrontal cortex works when we use chunking to help our working memory [1]. The scientists looked at how people's brains worked using a machine that measured their brain activity while they either used chunking or did not use chunking to remember information. How do you think using chunking affected how much these people used their prefrontal cortex? Do you think people used their prefrontal cortex more or less when information was chunked?

As you learned with the gift card example above, when information is chunked, you need to remember fewer pieces of information. If the prefrontal cortex is used to hold the pieces of information, then perhaps people use their prefrontal cortex less when they "chunk" because there is less information to remember? However, that is not what happened in the experiment. Scientists found that people used their prefrontal cortex *more* when they used chunking, as compared with when they did not use chunking. Even though people had to remember fewer pieces of information when they used chunking, they had to use more thinking, planning, and strategy to do chunking. So, from this experiment, we now know that the prefrontal cortex is not in charge of

FIGURE 1

Schematic drawing of important brain regions supporting working memory (prefrontal cortex) and long-term memory (hippocampus and perirhinal cortex). This figure was adapted from http://www.bristol.ac.uk/synaptic/pathways/



storing the information for working memory, but is instead responsible for the planning and thinking that allow working memory to use chunking.

LONGING FOR A GOOD LONG-TERM MEMORY

LONG-TERM MEMORY

Memory storage that stores information for a long time.

RECOLLECTION

A way to bring information to mind that makes us think really hard. We can use it not only to remember one thing but also to remember relationships between two or more things. It is supported by the hippocampus part of the brain.

HIPPOCAMPUS

A part of the brain that is responsible for recollection. It is deep inside the brain, and it is shaped like a seahorse.

FAMILIARITY

Bringing information to mind in a fast, quick, and easy way to remember one single thing. You may not have a clear memory of the thing you are trying to remember, but it "feels" correct. It is supported by the perirhinal cortex area of the brain.

PERIRHINAL CORTEX

A part of the brain that supports familiarity. It is located close to the hippocampus and receives information from other parts of the brain that take in information from the five senses.

We now know how chunking can help us have a better working memory. Increasing how much we can hold in our working memory can be very useful when we only need to keep things in mind for short amount of time. However, there are many times when we need to store information for more than a few seconds, so that we can bring it back to mind later. When we need to remember something for a long time, we use **long-term memory**. An example of this is remembering a baseball game that you won or remembering the time that you felt the cool breeze on your face after a hot summer's day. Long-term memory is not perfect, and sometimes it takes a big effort to remember something or we will forget it. So, how can we get a better long-term memory? We will come to that in a moment. First, we need to learn more about long-term memory.

Scientists have shown that there are two ways to bring to mind things that we stored with our long-term memory. These ways use different brain areas and take differing amounts of effort. One way is called **recollection**, and it makes us think very hard [2]. We can use recollection to remember any one specific thing. For example, if you see your school's librarian in a coffee shop on a Saturday, and you bring to mind that she is the librarian. We can also use recollection when we need to remember two or more things that are linked with a relationship. For example, when you have to remember that your school's librarian gives you the ticket for the bus home. In this case, you need to remember more than just the librarian and the bus ticket – you also need to remember the relationship between these two. Scientists have discovered that the part of the brain used to do recollection and to bring to mind such relationships is called the **hippocampus**. This brain area is shaped like a sea-horse and is buried deep inside the brain. You can see where the hippocampus is in the brain in Figure 1.

The second way to bring to mind things from long-term memory is **familiarity**, which is quicker, easier, and is a less effortful way to remember [2]. We can use familiarity when we remember one single thing, but usually not when we need to remember relationships between several things. For that we need to use recollection. (We could also use recollection to remember one single thing, as described earlier, but this is harder, so we usually use familiarity if we can.) With familiarity, you might not be able to clearly bring to mind how you know the librarian when you see her in the coffee shop on Saturday, only simply that you know her from somewhere. However, if your mom suggests, "Isn't that your school's librarian?" then your brain recognizes this as being correct because it feels right. When we use familiarity, we use a part of our brain called the **perirhinal cortex**. The perirhinal cortex is very

close to the hippocampus and receives information from other parts of our brain that take in information from our five senses; you can see where it is in the brain in Figure 1.

What if we could somehow remember relationships between multiple things using the quick and easy method of familiarity, instead of using the more difficult method of recollection? If we could do this, then we could make our long-term memory better because it would be easier to remember information. Experiments conducted in our laboratory and in other laboratories have found that we can use familiarity instead of recollection by using a type of thinking called **unitization** [3–5]. Unitization is a way to bind several pieces of information together into one piece of information for storing in our long-term memory. It works by us making-up (or imagining) a new important relationship that ties together the things that we want to remember. Scientists have discovered that we use our perirhinal cortex more when we use unitization to bind things together than when we do not use unitization.

UNITIZATION

A way to bind several pieces of information together into one piece of information for storing in our long-term memory.

Returning to our example from before, imagine that you need to remember that your school's librarian gives you the ticket for the bus home. You can make up a definition that combines the two ideas into one meaning. So, you think, "Librarian Bus" and then imagine that it is a special kind of bus that drives librarians to the local library. You can use your imagination to create pictures in your mind that are similar to the ones shown in Figure 2.

When you need to get your ticket, if you have used unitization, then your brain can immediately recognize that librarian "feels right," using the important link you made tying these two things together to only make one thing. So, now you do not have to think so hard to remember where to get your ticket from – you will immediately recognize that the bus ticket and the librarian go

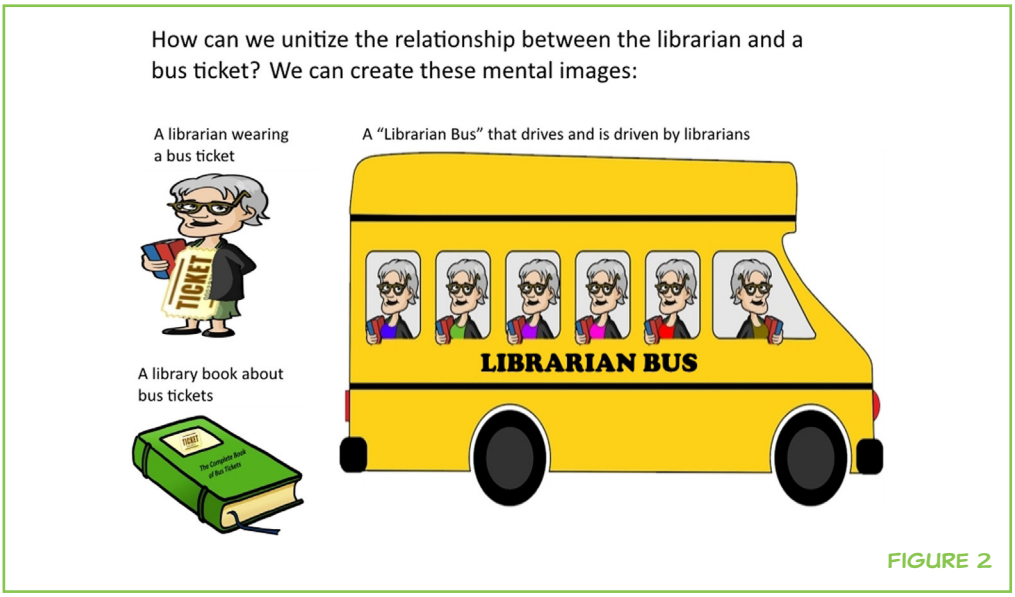


FIGURE 2

FIGURE 2

Examples of possible images that could be created in your head to unitize the relationship between the librarian and a bus ticket: a librarian wearing a bus ticket, a library book about bus tickets, and a "Librarian Bus" that drives and is driven by librarians.

BOX 1 – WHAT UNITIZATION PROCEDURES CAN WE EMPLOY?

You already know that when we use a concept or new definition to bind two pieces of information together, these words can become unitized and work together as a single unit. But, there are other ways you can form unitized ideas. Here are a few examples:

- Try to imagine the two items interacting with each other. For example, if you want to remember that you need to see the librarian because she is giving out the bus passes, then try to imagine that the librarian is driving the bus, and that she is also all of the passengers on the bus. It does not matter if the image is unrealistic, as long as the two items interact in some way.
- You can also try to think of some realistic connections between the items. For instance, if you know that the librarian always takes the bus to work, try to use this information to relate the items "librarian" and "bus" when you save them for later. This will increase your ability to see them as one thing.
- It is easier to unitize items that are presented to the same sense (hearing, sight, etc.), compared with items that are presented to different senses. So, if you want to remember that you have heard the librarian's voice while seeing the bus passing by, try to create a visual image in your mind of the librarian and the bus, or to imagine the voice of the librarian talking while the bus is whooshing.

well together. Can you come up with your own definitions to help you remember that Europa is one of Jupiter's moons, that Benjamin Franklin discovered electricity, and that bacteria only have one cell? For more ideas that will help you bind several items into a one single idea, see Box 1.

CONCLUSION AND OUTLOOK

Using ways of thinking that tie together, or *bind*, several pieces of information into one single piece of information means that we can fit more into our memory, and it can help us remember information better. The type of remembering used for information that is linked together can be quite different from the type of thinking used for only one piece of information, and we use different parts of our brain for these different types of memory. When we bind things together, so that we can remember information for short time periods in our *working memory*, we refer to it as "*chunking*." We use the part of the brain called the *prefrontal cortex* to do this, and it is in charge of planning and organizing our working memory. When the binding helps us store things for a long time in our *long-term memory*, we call it "*unitization*." Unitization allows us to use *familiarity* to remember information quickly and easily (automatically), and we use a part of the brain called the *perirhinal cortex* to do this. Using these different kinds of binding can help our memory, such as when we are studying for exams.

FURTHER READING

If you want to learn more about how our memory works, you can go to this site: http://science.howstuffworks.com/life/inside-the-mind/human-brain/human-memory.htm. You can also read these Frontiers articles http://kids.

frontiersin.org/article/10.3389/frym.2016.00005, http://kids.frontiersin.org/article/10.3389/frym.2014.00023 that explain about the human memory but from a different perspective than our article.

Watch this video https://www.youtube.com/watch?v=KkaXNvzE4pk that explains more about the hippocampus, why we need it and how scientists discovered what it does. Watch this video https://www.youtube.com/watch?v=UWKvpFZJwcE to learn what working memory is good for and how you can improve it.

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REVIEWED BY

EASTERLY PARKWAY ELEMENTARY SCHOOL, 9–10 YEARS OLD

Our school is very diverse with students represented from 21 different countries. Mrs. Finley's 4th graders have been spending this year learning a lot about how the brain works and practicing mindfulness and meditation. They love reading, are extremely hard workers, and are interested in learning as much as possible about science. The students who reviewed this article are Bella, Yazeed, Raina, Evan, Judah, Maya, Micah, Jack, Dennis, Blake, Ryan, Majid, Aqila, Alex, Simon, Caleb, Catherine, Jay, and Mamby.

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In my studies, I am especially interested in how our brains remember relationships formed between two or more items. I want to understand the processes that help up remembering this kind of information for long durations. When I am not doing science, I enjoy reading, writing, watching movies, and traveling. But most of all I love spending time with husband, my 4 year old daughter, and my newborn son – playing, drawing, learning, or just goofing around. *roni.tibon@mrc-cbu.cam.ac.uk

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As a scientist, I investigate memory and specifically study what happens to our memory as we get older. When I am not conducting my experiments, I like to spend time with my friends and boyfriend, to hang-out with my cat while watching TV, reading a book or listening to the radio, and to plan my vacations to new places. I especially like it when it is sunny and hot outside. *elisa.cooper@mrc-cbu.cam.ac.uk