Attention and Working Memory

Introduction

In chapter 6 you read about H.M. and were introduced to the idea that the explicit memory that we hold of something (a fact, a meaning, and idea) for a few seconds (short-term memories) is different to memories that we can recall over an extended period of weeks or months (long-term memories). In chapter 1 I defined learning as involving 'a relatively permanent change'. To put this differently, learning implies long term memory, and it is long term memory that ultimately is of interest to us. On the other hand, you have also seen that the two are related: explicit memories are first stored in the short-term and only then can these be transformed into long term memories under the right circumstances. If an explicit memory has never been held in the short term, it will never become a long term memory; it will never be learned. For explicit memories then, the first step in learning involves short-term or working memory.

In the next chapter I will look at how these short-term memories can become long term. But first, in this chapter, I will look at the way in which we hold memories for a short period of time in our working memory.

Short Term Memory – A limited resource

Below is a list of letters. Look at the list for 10 seconds, and then cover it. Wait 20 seconds and then try to recall the letters in order.

A H E F L E W O V R P S D Y

How many did you get right? If you are like most people you will remember between 5 and 9 of these letters. This finding is consistent with one of the most cited papers ever published in psychology: "The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information" written by George Miller of Princeton in 1956. The idea that we can hold 7±2 items in our short term memory is sometimes called *Miller's Law*. Without getting caught up in the number 7, the key idea in Miller's Law is that *our ability to hold things in memory over a short period of time is limited*.

What did you do to try to hold the list of letters in your head (I might rephrase that as asking 'what mental procedure did you use to hold on to the memory?')? Again, typically people give one of two answers to this question:

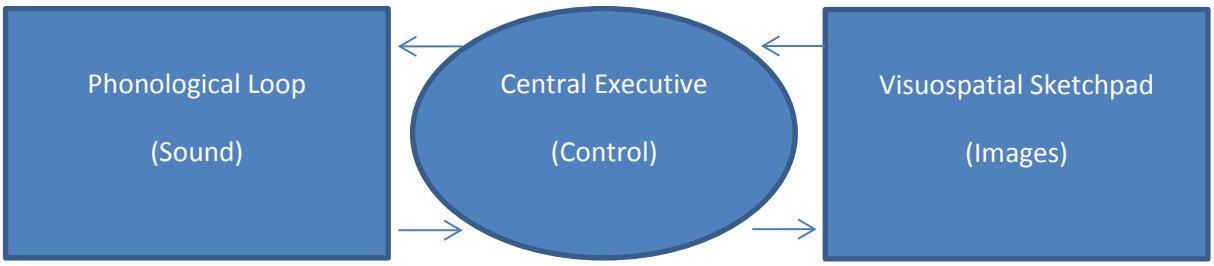
- They tried to repeat the letters over and over in their head like a short, internal sound loop running over and over
- They tried to visualise the letters and to see them in their minds eye.

It seems evident that we have at least both a mind's eye and a mind's ear which each play a role in short term memory. However, there is also a third element that is present but hidden in these two bullet points; in addition to having a system for sound and a system for image, we also system which manages the functions of the other two elements. This idea is fundamental to the distinction between being able to remember a list of times in the short term (called short term memory) and being able to work with and process those items. This is called *working memory*, and can be defined as a system which provides for both temporary storage and manipulation of information (See Baddeley, 1992).

The most widely (although not universally) accepted working memory model, was originally developed by Alan Baddeley and Graham Hitch from the University of York in the UK in the mid-1970s. Baddeley and Hitch's original model had three elements:

- *A phonological loop*: a system which enables the repeated, internal playback of a short 'sound' file (I put the word sound in inverted commas because the 'clip' is normally rehearsed silently, even if it has the same character as sound in your mind). The sound clip in question is sometimes argued to be about 2 seconds long. Some have argued that rather than the working memory being able to hold 7 distinct items, in fact it holds a clip of sound that is long enough to hold about seven letters or numbers.
- *A visuospatial sketchpad:* a system which allows for an image to be stored for a short period of time.
- *A central executive:* a system which manages the functions of the other two elements, such as, for example, ensuring that the sound file is repeatedly played over and over until it is required.

The original working memory model of Baddeley and Hitch (1974)…



Working memory – allocating attention

Read the following sentences. For each sentence: (a) decide whether the statement is true or false and (b) at the same time, remember the last word in each sentence. Try to do this without looking back at previous sentences.

Dogs have ears.
Cats read philosophy.
Sausages grow on trees.
Milk comes from cows.
Wood floats on water.

Vampires crave tea.

In this task, you are being asked to focus attention on two different things at the same time. On one hand you are deciding is the statement true (Yes, dogs have ears; no, cats do not read philosophy) and, at the same time, remembering the last word in each sentence ('ears', 'philosophy', 'trees'). As you might expect, it is relatively easy to do this for a small number of sentences, but as the number of sentences and words to remember grows, the task becomes harder to complete successfully. (In the last chapter you were asked to complete a problem which involved calculating how many oranges could be bought it you knew how much money you had, how many apples had already been bought and the price of both apples and oranges: that too was a task which required holding different elements in mind at the same time as processing information).

Why is it harder to do these tasks when more elements are involved? The answer appears to be that this task involves dividing your attention that we have only a limited ability to divide attention. If you think back to the idea of a central executive element in working memory, one of its roles appears to be to allocate some resource to different tasks. That resource is *attention*.

This idea should not be all that surprising. As I noted in the last chapter, when you are learning to drive, for example, it can be difficult to have the radio tuned to music that you like or to a discussion that you find interesting. Your attention becomes divided between the many tasks you need to complete to operate the car (gear, clutch, mirror, wheel, brake, watching the road) and the sound on the radio. One recent study found that when novice drivers listen to music that they chose when driving, their mood when driving is better, but they make severe miscalculations and errors more often, they violate more rules of the road, and they drive more aggressively (Brodsky & Slor, 2013) (again, our mood . Another review of evidence suggests that about a quarter of all driving accidents are due, in part, to the driver being distracted by a something other than driving (Young and Salmon, 2012). Attention is a limited resource and we need to be careful about where we direct it.

If you look back at the working memory model above, you will see that it is a system for managing sound and image – that is, it is about what we perceive and what we do with what we perceive. Of course, we are constantly surrounded by perceptual information. In any given second our eyes, ears, nose, skin and mouth can take in vast quantities of information. The fact that we are not overloaded by such information suggests that we have some process involved in 'filtering out' much – if not most – of the information at our disposal. In this sense, you can think of attention as being like a spotlight which we direct towards particular elements of our environment. This can be seen in operation in a number of ways:

- If you are in a quiet countryside and you suddenly hear a load bang intended to frighten birds away from crops, it will almost certainly attract your attention. If it keeps happening, however, you will start to 'filter it out' and after a while it will no longer distract you from other tasks.
- If you are in a party or a noisy bar, you may be surrounded by noise but will still usually be able to 'filter out' much of it in order to listen to the person you are talking with. Even though you are not listening to the background noise, however, you may find yourself being distracted if someone speaks your name.

- When expert teachers and novice teachers watch the same video of a classroom situation, expert teachers notice different things than novices. While they all receive the same perceptual information, it is filtered differently by experts and novices (Sabers et al, 1991). The same is true of other expert judgements – expert fire fighters notice different things than novices when they first arrive at a fire and consequently make different initial judgements (Klein, Calderwood & Clinton-Cirocco, 1986).
- One of the most famous examples of 'filtering out' attention is the case of 'The Invisible Gorilla' – an experiment devised by Christopher Chabris and Daniel Simons of Harvard (if you have not already seen their video, watch it on: http://www.youtube.com/watch?v=vJG698U2Mvo before reading any further!!!) The test involves a video of two teams passing a basketball. Viewers are told to count how many times one team passes the ball. While the teams play, a person dressed in a Gorilla suit enters the screen, wanders through the players, turns to the camera, beats her chest, and leaves. When Simons and Chabris (1999) asked participants if they had seen the gorilla 56% of participants had been so focussed on counting passes that they had missed the gorilla entirely (!)

In these examples above you can see that there are in fact two different types of attention. When you are disturbed by a loud noise or by someone in the background at a party speaking your name, this is *stimulus-driven attention*. Stimulus-driven attention shows that, even if System 2 is not consciously paying attention to your environment, System 1 is continuing to monitor it for potential issues or threats. Once that you have established that the distracting stimulus is not a threat (such as with the crow-scaring noise) it drops out of your attention spotlight. The second type of attention evident here is *controlled attention*. When you make yourself pay close attention to something (like in the Gorilla experiment, or indeed, when trying to learn something from a text), you are controlling and directing your attention. When you are in the party and are trying to listen intently to what your partner is saying despite all the noise, you are again controlling attention. It is controlled attention which is central to studying and to working in an environment which is often full of ringing telephones, chiming texts and Facebook notifications, pinging emails, and chatting colleagues.

Maximising the Potential of Working Memory

Below is a list of numbers. Look at the list for 10 seconds, and then cover the page. Wait 20 seconds and then try to recall the numbers in order.

1
8
5
0
2
5
3
7
0
4
9
6
5
3

You probably find it challenging to remember the whole list of numbers. This is not surprising as the list is longer that the 7±2 numbers that we can typically accommodate. But imagine the same numbers are organised like this:

1 8 5 0 - 2 5 3 - 7 0 4 - 9 6 5 3

Organised like this, it looks more like a phone number and will probably be easier to remember. Why? Because, presented in this way, people do not usually try to remember 14 individual numbers, but instead try to remember 4 blocks of numbers. In his classic paper on the 'magic number seven' Miller referred to this as *chunking.* The same practice can also be used to hold long term memories in ways that make it easier for them to be recalled. For example, earlier we came across one such technique in relation to personality: by taking the unfamiliar words Openness, Conscientiousness, Extraversion, Agreeableness and Neuroticism and organising them in terms of their first letter [O-C-E-A-N] we make it relatively straightforward to remember something that would normally difficult to recall. Students starting to learn music often remember what note corresponds to each mark on the page by using mnemonics such as 'Every Good Boy Deserves Fruit' and FACE (the notes on the five stave lines are E-G-B-D-F, the notes between the lines are F-A-C-E). These techniques for aiding memory performance are called *mnemonics.*

The missing piece – the Episodic Buffer

One of the factors that perhaps makes these mnemonics relatively easy to remember is that they can potentially be stored as images as well as words. To remember the Big-5 personality factors, we can imagine an image of standing on a beach, flanked by rugged cliffs and watching a rolling steel-grey body of water stretching out to the horizon. To remember how to read music we can think of a classroom in which, instead of the child giving an apple to the teacher, it is the teacher who is giving an apple to a well-behaved pupil. We can make sure that, in our image, the look on his face (FACE) is distinctive and also draws our attention.

This technique – using images to remember things – is well known and has a long history in western thought. Two thousand years ago people used techniques like this to remember long poems, and speeches. Indeed, in a time before books were cheaply and widely available such a skill was absolutely essential to being regarded as clever or wise. The technique – sometimes called the memory palace technique – involved thinking of a familiar place (your home, your route to work or to school), painting it for yourself in graphic detail, and then mentally walking through the rooms placing items you wanted to remember in the image. To remember the names of the psychologists who developed the working memory model for example, you might imagine a person in a lab coat, laughing and sneering maliciously (Bad-[deley]) while sticking his thumb out to catch (Hitch) a lift from a car. Perhaps the car that arrives has an old record player (a phonograph) instead of a CD or MP3 player, with a scratched record which keeps playing the same snippet of sound over and over again on a loop (Phonological Loop). Instead of a windshield, there is a whiteboard and one of the passengers is drawing what she things might be on the road outside, while another passenger rubs it out (Visuospatial sketchpad). The front of the car has three seats and in the middle seat of the car is the driver; she is wearing a pinstriped business suit and smoking a large cigar (the Central Executive).

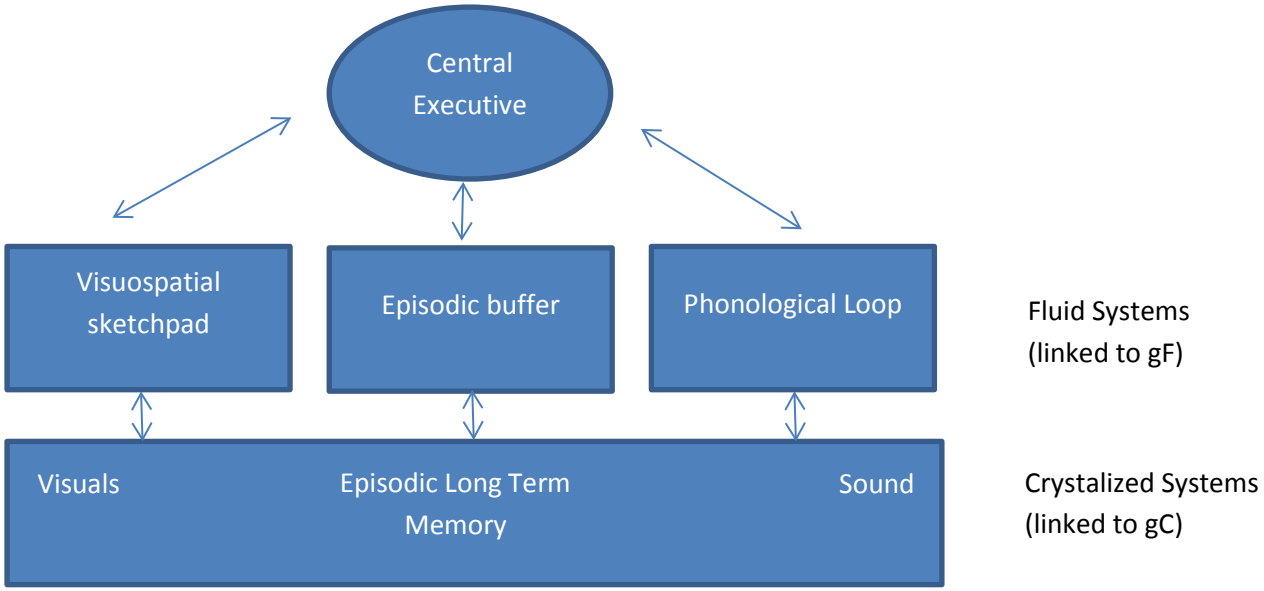
Once the memorable image has been created, you can place it along your memory palace route (say, outside your front door as you travel to work or college). Just up the road, you place the next memorable image that represents something else that you want to remember.

If you look again at this example, you will see a number of different elements:

- Sound and image are woven together – elements of the phonological loop and the visuospatial sketchpad are organised together in creating images
- There is a narrative or story element to the image - a timeline or a route that is followed and which makes the memories easier to recall

It could be that these kind of memory techniques represent the interaction of the working memory with long term memories. However, Baddelely found that the organising of words into sentences that made sense as a narrative was also evident in densely amnesiac patients who could not call on long term memory in this way. In order to account for this, Baddley (2000) proposed a new element to the model, one which is based on episodes or story: an episodic buffer. The episodic buffer played a role in linking both sound and images into story-like sequences (episodes),and, as the name suggests, is linked to episodic memories (memories of stories and events). In a sense, it can be seen as a memory storage function in the central executive but one which links to provides a space between (the two other perceptual systems (it is in this sense that it is called a 'buffer').

... The updated Working Memory model Baddeley (2003)



Conclusion

To learn a semantic memory – the kind of memory that is most often regarded as important and taught and assessed in formal education – we need first to pay attention to it. Unfortunately, we have only a limited amount of attention available to us. This puts immediate limits on what we can learn. It doesn't take much for our attention to be filled to overflowing. Avoiding unnecessary distractions (stimulus-driven attention) is obviously therefore useful for learning. Maintaining controlled attention in the face of distractions is also clearly a factor in learning.

Our attention systems appear to include at least (a) a sound component, (b) a visual component, (c) a story component and (d) a system that manages the other three. This last system allows us to hold something in our attention, but it also allows us to work with and manipulate the information that we are holding.

Animals, including humans, have developed some ways to cope with the limits of our attention. The most obvious is that, when things are learned well enough they become procedures and can run without requiring our attention. As we saw in the last chapter, this can give rise to its own problems (remember Frederick's Cognitive reflection Test), but it does at least free up space in the working memory.

Within working memory itself, we also have some strategies that help us cope with our limitations. We can reorganise elements into groups (chunks). This allows us pay attention to a smaller number of groups/chunks rather than a large number of individual elements. We can also organise things so that they follow each other like elements in a story. This too makes it easier to hold on to them.

Since semantic memories need to be held first as short term memories before they can be turned into long term memories (that is, before they can be learned) the operation of working memory and attention is crucially important for learning. The correlation between working memory capacity and fluid intelligence has been estimated to be as high as 0.6 to 0.8 (Klingberg 2009: 42)! However, as I noted in the introduction, holding an idea for a short period of time is not in itself enough to be considered as learning. For that, the idea needs to be stored in long term memory. It is to that that I will now turn.