

NEUROSCIENCE COURSE
MODULE 2

Module 2 :

MEMORY

The subject of memory is closely linked to the topic covered in the next module, learning. They echo each other so much that we could have discussed them in just one module. However, as there is a large amount of information to cover, we decided to address them in two parts.

Before we get started on analyzing the topic, let's begin by considering the case of Mrs. X, aged 62, who has relatively advanced Alzheimer's disease. The snippets of memories she has left are so small that she no longer recognizes most members of her family, apart from her grandson. It would be an exaggeration to say she always recognizes him, but she manages from time to time. What is certain, however, is that she loves spending time with him and is calm when she is with him.

In contrast, she is particularly aggressive with other patients, her carers, and even the other members of her family. There is nothing particular about her grandson, other than the fact that he plays the violin to her whenever he visits. When he is there, she seems to rediscover her personality. She doesn't remember everything, of course, but part of her life comes back to her. The question is, why does Mrs. X only remember her grandson?

Here's a second example that will speak to all parents. In the first few days after birth, babies are mainly receptive to the voices of the people around them. After a month, sight begins to play an important role. What's more, babies already have their favorites: the presence of certain people makes them happy, while that of others upsets them. But how do babies manage to recognize the people around them?

In a broader sense, how does memory function? Why is some information forgotten in a few minutes or even seconds, while other information remains etched in our mind forever? This is what we will examine in this module, in addition to memory assessment techniques and ways to improve memory.

The structure of memory

It would be impossible to give a definition of memory without addressing the process of memorization. This takes place in three main steps: encoding, storage and retrieval of information.

🌟 **Encoding – Main parts of the CNS involved: Hippocampus, left frontal cortex**

In the past, it was thought that efficient storage of a piece of information was closely linked to the transit time in the short-term memory. As such, it was advisable to mentally retain the information as far as possible in order to increase the latter. This process, known as maintenance rehearsal, does give good results, but only in a relatively limited percentage of people.

Indeed, the main disadvantage of this rote repetition is the fact that it needs to be permanent. In the hours and even days after the final repetition, the information will remain anchored in the mind. After a few weeks, however, you need to resume the process in order to store information again, even though it is supposed to have been acquired. Worse still, in many cases the subject only retains some of the information learnt.

A few decades ago, researchers finally addressed the problem in a different way, and to do this, had to understand a relatively simple precept: that the human brain is not like the hard disk of a computer. We do not simply accumulate information in the hope that new information will be added harmoniously to the previous information. Human memory is much more complex and mysterious.

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To encode a piece of information, the brain needs to perceive it in a context. Let's take a simple example: fire.

Perceived on its own, the information "fire" has little chance of staying anchored in the brain. If you explain to a one-year-old child what fire is, they will not be receptive because they do not know what it does in concrete terms. They are even likely to forget the word a few seconds later, regardless of how many times you repeat it to them. As their brain does not make a connection between this word and any other relevant information, it remains vague and will not be stored.

On the other hand, if you move the child's hand towards a fireplace and say the word "fire" to them, they will feel the heat and know that "fire" = burn = danger. You won't need to repeat the word to them so they retain it. They will make a very rapid association that will help them to encode this information. The information will be imprinted on their mind forever. As such, they will not only not get close to the fireplace and therefore not risk burning themselves, but their body will also react immediately if they ever hear "Look out! Fire!"

Encoding is only effective when the individual is able to codify and structure the information received. This is why the more past experiences an individual has, the faster encoding will be. Even without supply points and prior experiences, it is still possible to facilitate this process. There are several possible options:

- use a semantic strategy: associate words that will enable easy recall later (for example pepper = bright red).
- use a phonological strategy: use the letters in the word as anchors (for example pepper = P like piquant).

All the sensory organs can be called upon; we could return to the example of fire to demonstrate this. The more encoding parameters there are, the more effective the latter will be.

★ Storage – Main part of the CNS involved: neocortex

There are no storage areas as such; rather, we refer to recognition areas.

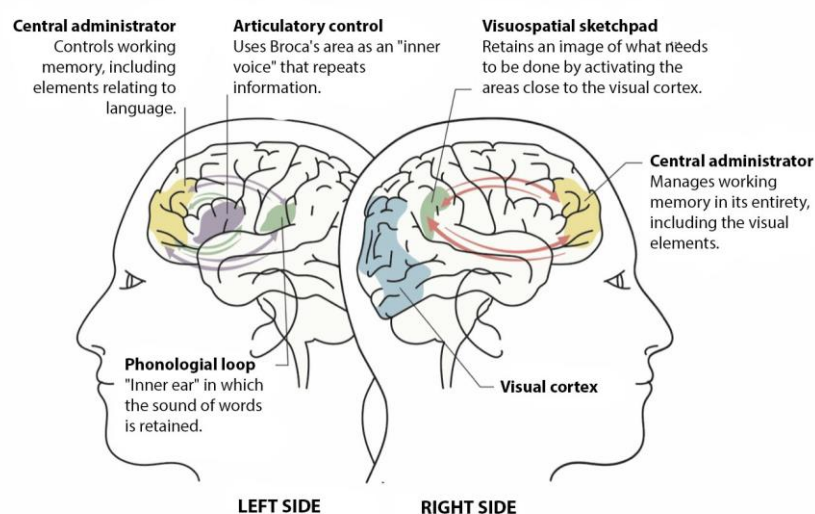


Figure 1: The areas of the brain that are relied upon in working memory.

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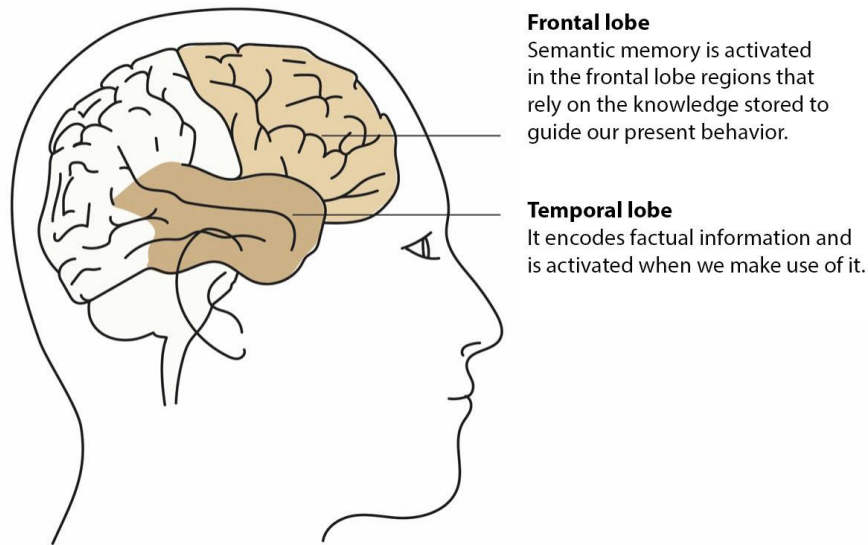


Figure 2: The two lobes that are activated in semantic memory.

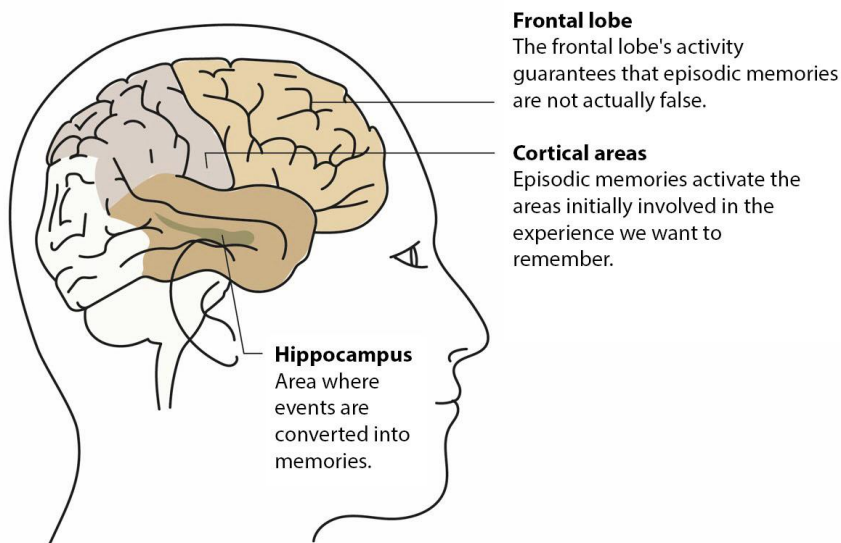


Figure 3: The areas of the brain that are involved in episodic memory.

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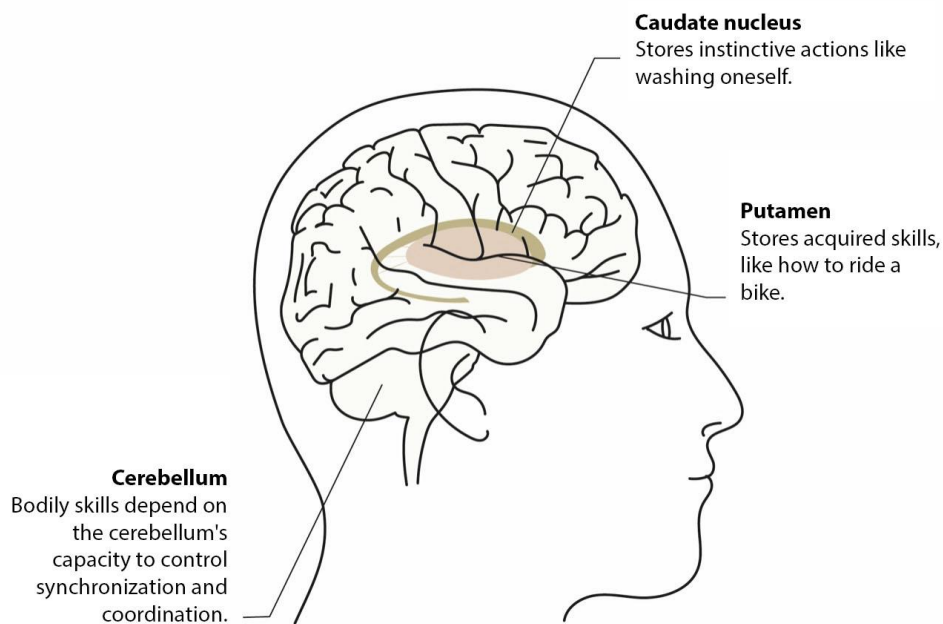


Figure 4: Long-term procedural memory involving the cerebellum, caudate nucleus and putamen.

We often hear how we only use 10% of our brain's capacity. In reality, we still rely on the image of a person whose brain functions at 100% and who retains all the information they receive. Recent studies have shown that the brain's memory capacity is in fact 10 times higher than we once believed.

In 2015, Terrence Sejnowski et al published an article in the scientific journal *Life* that shook the world of science. Studies they conducted proved that the nerve cells' storage capacities were far greater than we expected. We'll look at these studies in more detail in a moment. Before this, however, we need to explain a key point: how does data storage work?

One of the most active structures in the memory process is the hippocampus. This organ primarily facilitates the management of declarative memory. However, it is rather thanks to all the neurons than to the synaptic network that information is stored.

To retain information, the brain will repeat it constantly, unbeknownst to the individual, until it is useful to it again. Data storage is both a chemical and electrical process; all the encoded information remains in the synaptic network waiting to be removed or reused. Thus, the larger and more active the synaptic and neuronal network is, the easier it will be to encode and store information.

How was Terrence Sejnowski's study revolutionary? It all comes down to the synapses. Until this study was published, it was thought that there were three categories of synapses based on their size: large, medium-sized and small. The difference in size between the different synapses is quite significant in order to be visually noticeable. Until this point, the scientific community systematically put synapses that differed in size by around 10% in the same category.

The team who wrote the article carried out experiments on a rat hippocampus with a view to studying an anomaly that had been noted previously: some of the neurons analyzed transmitted dual signals one in ten times, i.e., more frequently than was thought to be the case. To understand the origin of the problem, the researchers analyzed the size of the synapses responsible for transmitting this dual

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message and that of the neighboring synapses, which emitted one signal. It turned out that the difference in size was not even 10%, but rather a maximum of 8%.

After calculations, it became clear that there were not three different sizes of synapses as had always been believed, but rather 26. Moreover, the size of each one was found to vary based on the information received. This means, as Thomas Bartol Jr. states, that “every 2 or 20 minutes, your synapses are going up or down to the next size. The synapses are adjusting themselves according to the signals they receive.”

From a computing perspective, these 26 sizes correspond to 4.7 bits, which is equal to more than twice the previous data. In short, if we stay in the domain of computing, this is like saving up to 1 petabyte of data (1 million GB), which is 10 times more than what the scientific community used to think.

🌟 Retrieval of information – Main parts of the CNS involved: hippocampus, right frontal cortex

The process of information retrieval is closely linked to the encoding mechanism. The more encoding parameters there are, the faster the retrieval process will take place. There are several categories of memory activation and memory retrieval:

- free retrieval;
- cued retrieval;
- ordered retrieval;
- immediate retrieval;
- delayed retrieval;
- recognition.

Free retrieval (or free recall) – This is the free retrieval of retained information. The adjective *free* is used in the sense that retrieval of acquired information can occur in any order. If we consider a poem, for example, the individual is not obliged to recite it verbatim. It is enough for them to remember all the lines in the text, regardless of the order.

Cued retrieval (or cued recall) – In this case, the individual receives anchors, clues that they use to recover buried memories. Note that this technique only works if the encoding is done using the same clues. Let’s take the following example: a blue glass given to Paul for his birthday. If the individual has seen the blue glass but doesn’t know it was Paul’s birthday or that the blue glass was given to him, it is unlikely that the information will come back to them.

Ordered retrieval (or ordered recall) – This is the most complex form because it requires the subject to remember the most minute details of a piece of stored information perfectly.

Immediate retrieval (or immediate recall) – Immediate recall is when the gap between encoding, storage and retrieval is a few seconds, for example if someone has just shown you a photo of a person, then you look up and that person is standing right in front of you.

Delayed retrieval (or delayed recall) – When the gap between storing information and retrieving it is a few minutes, this type of recall is considered delayed. Recall is delayed even if the interval is only a minute.

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Recognition – In this case, the information stored by the individual is placed in the middle of a mass of unknown information and it is up to the subject to find it.

On the whole, memory is an important stage of development. It is the most significant survival tool that humans (and animals) possess. It can be studied from several perspectives, but we can limit ourselves to just two: biological and psychological.

From a biological perspective, memory is simply about storing information and past experiences. The process can be likened to a form of storage. The least important information is eventually deleted, while the most important information remains anchored in the memory for as long as possible.

From a psychological perspective, memory is a more complex mechanism. It is not only about storing all the information received in the mind. The individual is also responsible for analyzing it and drawing the necessary conclusions. Thus, from being a simple storage operation, memory becomes an analytical process. Ultimately, memory becomes an operation that involves encoding, storing, analyzing and retrieving information.

The different forms of memory

Rapid memorization of information that has limited use and of crucial data does not happen in the same place or the same way, hence the importance of structuring memory. There are several memory-related mechanisms:

- ➔ short-term memory (STM);
- ➔ long-term memory (LTM);
- ➔ sensory register (SR).

★ Short-term memory (STM)

This is the storage mechanism for a limited amount of information for a limited period of time. The information in the short-term memory can then be sent to the long-term memory or erased. This mechanism always rests on two pillars:

- ➔ duration;
- ➔ amount.

Duration – Short-term memory generally retains information for a maximum of 30 seconds. It is possible to increase this, but it will not reach one minute.

Amount - The amount of information that can be stored during this period of time is generally very low. Here's a typical example that is often used to illustrate this. If you give an individual 10 to 30 seconds to remember 10 numbers, they will remember a maximum of 7. Only people who constantly train their memory will be able to remember more.

Short-term memory is only supposed to retain information that is useful immediately or in the following seconds and minutes. When we listen to a sentence, for example, we can only understand the end if we remember the beginning. This type of memory is a kind of vestibule. We have access to it before opening the doors to long-term memory. This is why problems with short-term memory can also lead to difficulties with long-term memory.

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★ Long-term memory (LTM)

Click on [this link](#), then close your eyes and simply listen to the music. Then open your eyes and choose one of the following adjectives to describe the cultural origin of the melody:

- ➔ American;
- ➔ Irish;
- ➔ African;
- ➔ Arabic.

Then try to explain your choice before looking at the information connected to the video. Few people will know this composer or have listened to their work before. Like many other people, you will no doubt have thought it was Irish music rather than African, American or Arabic. And why? Because of long-term memory.

After listening to this type of music once or twice, the brain registers it and associates similar sounds with it. Thus, we might be wrong about where the composer comes from, but the sound remains engraved in our memory forever. Note that the information contained in long-term memory will not necessarily stay there until the end of an individual's days.

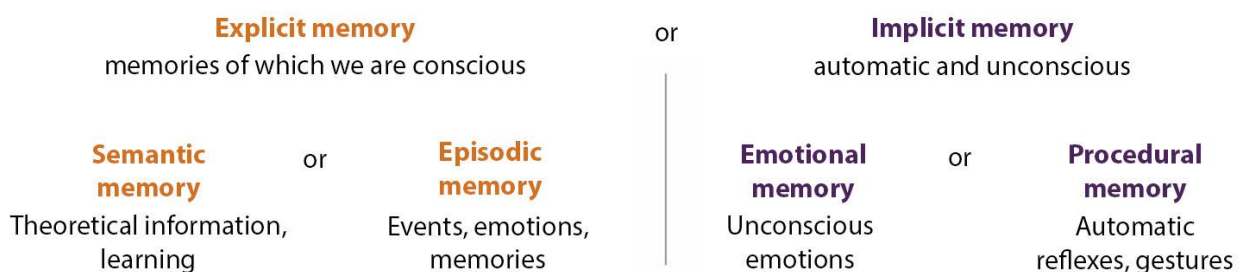
From a cognitive psychology perspective, long-term memory is defined as what allows us to retain as much information as possible for an unlimited period of time. Long-term memory is not a fixed environment. It is divided into two main classes:

- ➔ declarative memory (or explicit memory);
- ➔ nondeclarative memory (or implicit memory).

These two main categories are divided into several subcategories in turn:

- ➔ procedural memory;
- ➔ episodic memory;
- ➔ emotional memory;
- ➔ semantic memory.

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★ Declarative memory

Also known as explicit memory, declarative memory is what individuals employ consciously. It deals with entities considered to be encoded symbolically and that can therefore be described using language. In short, declarative memory, as the name suggests, is the type in which information can be expressed verbally. It comprises episodic and semantic memory.

➔ Episodic memory

This type of memory stores the events individuals have experienced at a precise moment in their existence. This is why it is also known as autobiographical memory. This type of memory stores not only situations experienced, but also the contexts in which these events occurred.

➔ Semantic memory

This type of memory retains all the encyclopedic knowledge acquired. The text you are currently reading will be stored in this form of memory. It offers the advantage of being much more precise than episodic memory.

★ Nondeclarative memory

Nondeclarative memory, or implicit memory, is where knowledge is expressed in a different way than in words. If we print a text on a computer, pilot a plane or drive a car, we are using implicit memory.

Let's take the example of someone who needs to print a text. Implicit memory will retain only the operations necessary to do so. It will not retain all the history linked to the development and use of the first computer. This information will be found in autobiographical memory.

Like declarative memory, implicit memory is also split into subcategories: procedural and emotional memory.

➔ Procedural memory

This type of memory retains all the motor skills, sensorimotor automatism and knowledge we acquire throughout our life. If you wake up one morning and are confused when you see your pair of trainers because you can't remember how to tie the laces, this indicates that the procedural memory has been impacted by trauma.

This type of memory is without doubt the most efficient of all. We sometimes forget words or information we have learnt, but this rarely happens with gestures and actions, especially if we are constantly repeating them. Procedural memory can also be classified in the family of explicit types of memory. If you were asked "How do you wash plates?", for example, it will be possible to explain the process in words without needing to use gestures.

➔ Emotional memory

As the name indicates, this type of memory retains all the conditioned responses and emotional conditioning. The information stored in the long-term memory can remain there for life. We all know, for example, that fire burns. From the second we realize this as children until our last breath, this is a piece of information that we do not forget. Even people with neurodegenerative diseases know this; in the event of a fire, you will not need to explain to them why it is important to get out.

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Other information is erased after a few months or years. Many people would be incapable of completing a math exercise that they completed with ease 10 or 15 years ago. The nerve connections responsible for storing this knowledge have disappeared with time due to not having been used.

Deletion of information is the result of three states: an emotional trauma, proactive and retroactive interferences, and synaptic suppression.

First state: emotional trauma – Emotional trauma can contribute to erasing information as much as it can contribute to conserving it. All students know this: nothing is as simple as learning a subject taught by a teacher we like. As complex as it might be, we will try our hardest, if only to please this teacher.

This emotional component will enable us to remember at least fragments of lessons given long after they cease to be relevant. There is no need to recall that the exact opposite is the case if the teacher seems boring.

A second example is selective amnesia, also known as dissociative amnesia or traumatic amnesia. This type of amnesia consists in forgetting part of an experience and/or temporality ranging from a few minutes to a few hours, when an individual has suffered a trauma. For example, someone who can't remember the minutes when they were raped but remembers what happened before and after. A person who has witnessed a violent event may also experience this type of amnesia.

This loss of memory can last for decades, whether total - the person has no recollection of what happened during the trauma - or partial - snatches of traumatic memory re-emerge.

The above examples do not necessarily mean that negative emotions automatically lead to us forgetting stored information. Extremely positive sensations can lead to the same result.

Second state: proactive and retroactive interferences – If the information acquired at a certain time interferes with that retained slightly earlier, it can be erased from the brain. Proactive interference occurs when old information suppresses the new. In the opposite case, when freshly stored information blocks old information, this is retroactive interference.

Third state: synaptic suppression – The synapse will be active for as long as it is required. When it ceases to be active or its level of activity is very low, it will disappear, and the information it transmitted will be erased with it.

The sensory register

This register can be considered one of the first forms of storing information. It only stores sensory information for a very limited period of time. This sensory memory is consistent with the amount of time perceiving the auditory or visual stimulus. There are two types of register:

- ➔ the visual sensory register;
- ➔ the auditory sensory register.

These memories do not persist for longer than 500 ms. It is generally between 300 and 500 ms. There are cases when stimuli received by other sensory organs add to these visual and auditory stimuli. The combination of all these sensory perceptions ultimately helps to communicate precise information.

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Several experiments have been conducted in this area, but the most famous example is still that conducted by Sperling in 1960.

🌟 Sperling experiment

In this experiment, George Sperling used a tachistoscope, a device that displays visual elements for a very brief period of time. He projected a stimulus card with 9 letters on it for 50 ms. The subjects then had to list the letters they saw. The result was that subjects' average recall capacity did not exceed 4 or 5 letters. Why? Sperling proposed two hypotheses:

- ➔ either the projection time was too short for the subjects to be able to identify the nine letters;
- ➔ or the subjects managed to perceive the nine letters but forgot some of them during recall.

The researcher carried out another experiment to try to establish the cause for this low recall capacity. Again, using a tachistoscope, he presented the subjects with a series of cards: the stimulus card with 9 letters on it (projected for 50 milliseconds), a blank white card, then a card with a mark on it (a small black square) to replace one of the 9 letters (projected for 50 milliseconds). The subjects then had to remember the letter that was hidden by the mark.

Thus, the recall results depended on the time of exposure to the white card: if it was less than 500 milliseconds, the researcher recorded 100% correct answers, whereas if it was more than 500 milliseconds, he recorded only 50% correct answers.

As such, the first hypothesis proposed was abandoned. The experiment shows that, for some time, the subject is able to answer regardless of the position of the square; thus, they have a memory. The subjects therefore continue with the 9 letters: the image has sensory persistence.

If they are no longer in the sensory register, they have moved into the short-term memory beyond 500 milliseconds. It is therefore a test of the short-term memory. The sensory register is a very rapid phenomenon. These are successive steps in the memorization process. Thus, the sensory register is the point of entry into the memory, first short term and then long term. The sensory register therefore provides a transition.

Schematically, using Atkinson and Shiffrin's model, we obtain the following graphic:

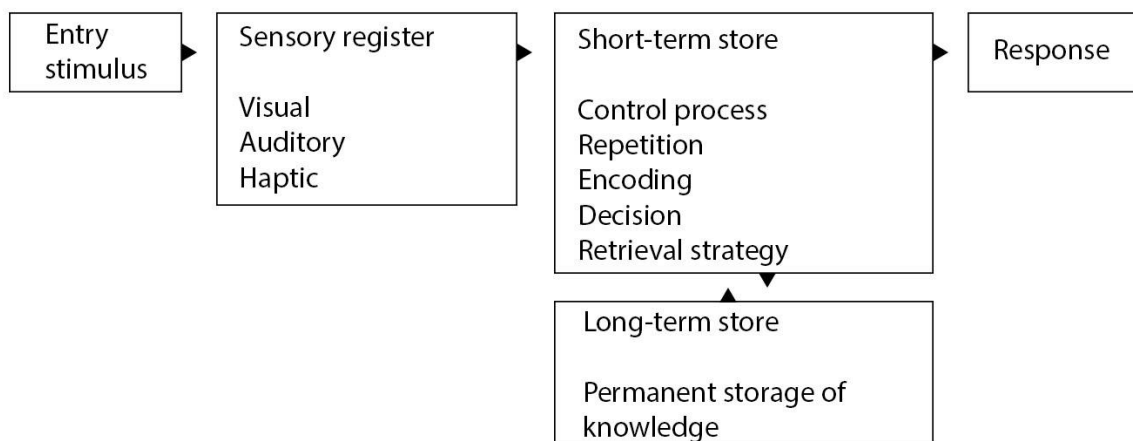


Figure 5: Simplified architecture of Atkinson and Shiffrin's model.

Neuropsychological evaluation

There are many techniques we can use to improve memory. However, before using any of them, it is important to assess the memory. If the test in question is required to assess the faculties of a subject who has a cognitive disorder or memory problems linked to psychological issues, a neuropsychological evaluation is required.

The process is divided into several steps and is intended to identify the patient's personality and difficulties.

- ➔ **Information gathering:** this step is about gathering all the information relating to the patient. No aspect of their life should be overlooked. If possible, conversations should be had with their family and friends.
- ➔ **Clinical consultation:** this involves direct contact with the patient, during which the specialist will analyze their behavior and also assess their overall memory and cognitive capacities.
- ➔ **Analysis of results:** once all the tests have been carried out and the important information obtained, a report is drawn up.

Out of the three phases, the consultation with the patient is the most important, because it helps to gather the majority of the useful information for the report. It is divided into two main parts: a behavioral evaluation and an assessment of their cognitive capacities.

★ Behavioral evaluation

Attention is focused on the patient's behavior, hence the importance of speaking to their close friends and family if possible. It is also necessary to assess their actions and attitude during the conversation, because these always provide an accurate reflection of the subject's state. Unjustified apathy and a reduced sense of initiative can indicate an injury to the anterior medial frontal cingulate cortex.

Symptoms like apathy, euphoria, irritability, depression, restlessness and disinhibition must always be taken seriously. It is not only the presence of these symptoms that matters, but also their frequency and severity. The sheet below indicates the elements that are helpful to dwell on during this evaluation.

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NEUROPSYCHIATRIC INVENTORY

NPI

Name: _____ Age: _____ Assessment date: _____

Position of the person interviewed: _____ Type of relationship with the patient: _____
Very close/provides day-to-day care;
Close/often looks after the patient;
Not very close/only gives treatment or has few interactions with the patient
NA = question not applicable F x S = Frequency x Severity

Symptoms	NA	Absent	Frequency	Severity	F x S	Effect
Delusions	X	0	1 2 3 4	1 2 3	<input type="text"/>	1 2 3 4 5
Hallucinations	X	0	1 2 3 4	1 2 3	<input type="text"/>	1 2 3 4 5
Agitation/aggression	X	0	1 2 3 4	1 2 3	<input type="text"/>	1 2 3 4 5
Depression/dysphoria	X	0	1 2 3 4	1 2 3	<input type="text"/>	1 2 3 4 5
Anxiety	X	0	1 2 3 4	1 2 3	<input type="text"/>	1 2 3 4 5
Elation/euphoria	X	0	1 2 3 4	1 2 3	<input type="text"/>	1 2 3 4 5
Apathy/indifference	X	0	1 2 3 4	1 2 3	<input type="text"/>	1 2 3 4 5
Disinhibition	X	0	1 2 3 4	1 2 3	<input type="text"/>	1 2 3 4 5
Irritability/lability	X	0	1 2 3 4	1 2 3	<input type="text"/>	1 2 3 4 5
Motor disturbance	X	0	1 2 3 4	1 2 3	<input type="text"/>	1 2 3 4 5
Total score for first 10 elements					<input type="text"/>	
<i>Neurovegetative changes</i>						
Night time behaviors	X	0	1 2 3 4	1 2 3	<input type="text"/>	1 2 3 4 5
Appetite and eating	X	0	1 2 3 4	1 2 3	<input type="text"/>	1 2 3 4 5
Total score for all 12 elements					<input type="text"/>	

★ Assessment of the subject's cognitive capacities

This encompasses several aspects, hence the need to adopt several approaches: psychometric, cognitive and anatomo-clinical. Specifically, it involves quantifying the subject's mental performance and any impairments. This information can help to position the individual on a specific scale.

Memory evaluation tests

Despite the many assertions we read sometimes, there are no standard examinations. Each specialist can devise their own tests, incorporating as many parameters as possible. However, they all need to meet two basic criteria:

- draw up a psychometric report that helps to gain an accurate understanding of the patient's state;
- have an in-depth preliminary conversation with the patient and, if possible, their family, to get a precise idea of their memory abilities and select (or create) the tests that the patient will need to take with a greater level of attention to detail.

Here is a list of the classic tests used in memory assessments, as well as the targeted areas.

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Cognitive functions	Neuropsychological assessment tools	Characteristics of the assessment tool
General cognitive functions Episodic memory	MMSE Mattis scale Wechsler memory scale 16-item free recall-cued recall test California verbal learning test Rey complex figure test Doors test	Recalling stories, studying pairs of words, reproducing images Studying a series of 16 words (Grober and Buschke's procedure) Studying a series of 16 words that belong to 4 categories Reproducing from memory a complex geometric figure Recognizing photos of doors
Semantic memory/ language	DO 80 Verbal fluency (semantic criteria) Test of semantic knowledge	Picture naming Producing as many words belonging to a given semantic criterion as possible orally Questionnaire on general and specific knowledge of concepts
Working memory	Test of semantic knowledge Digit span Brown-Peterson paradigm	Questionnaire on general and specific knowledge of concepts Repetition of ascending series of numbers Recall of series of 3 letters (or words) after a period spent doing an interfering task
Executive functions	Trail-making test (mental flexibility) Stroop (inhibition)	Connecting numbers and letters in order, alternating the 2 series Naming the color in which words (color names) are written, knowing that there is a discrepancy between the two (eg "red" is written in green)
Visuoconstruction skills	Wisconsin test Copying Rey's figure	Sorting cards based on different criteria Copying a complex geometric figure

Examples of options for assessing memory

★ Working memory

Working memory is assessed using three types of exercises:

- ➔ visuospatial and verbal span exercises;
- ➔ exercises to evaluate the ability to process or store information;
- ➔ exercises to evaluate memory flexibility and maintenance.

★ Episodic memory

Tests are divided into two main categories: tests to assess explicit memory and perceptual representation exercises.

➔ Explicit memory can be assessed through:

- ❖ free recall tests;
- ❖ cued recall tests;

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❖ recognition tests.

➤ Perceptual representation:

❖ perceptual priming exercises (these assess implicit memory capacity).

★ Semantic memory

Semantic memory is assessed through three types of exercises:

➤ conceptual priming tests (like those previously mentioned, these assess implicit memory capacity);

➤ verbal knowledge assessments;

➤ spatial knowledge assessments.

★ Procedural memory

Procedural memory is assessed through tests of skills.

Before starting to assess the patient, it is important to know that there are no static tests to assess memory as a whole. The tests used to evaluate short-term memory are not suitable for evaluating long-term memory. In the same way, tests to assess episodic memory cannot be used to assess semantic or procedural memory, etc.

Assessment tests must also take into account the patient's age, because the semantic memory of a 3-year-old child is not like that of an 18-year-old man or a 75-year-old.

Overall, tests can be grouped into two main categories: direct techniques and indirect techniques.

Direct techniques

For these tests, the patient is informed in advance of all the information they will need to reproduce. Very often, these tests focus on declarative memory. For example, a patient is asked to remember a list of X words for a certain period of time and then reproduce them in order or not.

The techniques used are as diverse as they are varied. They are based mainly on the type of encoding. There are the following methods:

➤ free recall method;

➤ cued recall method;

➤ ordered recall method.

★ Free recall method

This method is very popular, and for good reason: it enables the specialist to get an idea of the patient's ability to structure their memory. The free recall technique involves remembering as many initial items as possible, but at random. It has been proven that patients always remember items found at the start and/or end of a list better than those in the middle.

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★ Ordered recall method

In this approach, precision is essential. The subject receives a list of items given in a certain order and has to reproduce the information, adhering faithfully to this initial order. This is a relatively complex test that can be used to assess declarative memory.

★ Cued recall method

In the two preceding categories, the subject had to choose the technique for reproducing the information received themselves. Here, parameters are provided. Two techniques are particularly popular:

- the paired associate method: the subject is taught pairs of words, then they have to remember the missing word when provided with the hint;
- competitive techniques: these tests are not unlike game shows from the 70s and 80s; the patient gets part of the item and has to remember the item in its entirety.

With the free recall methods, we also add recognition tests. During these tests, patients are asked not only to recognize the items that were presented to them before, but also to remember the sequence in which these items were presented to them. Thus, it is not simply about remembering one concrete item, but rather seeing whether the subject can put this element back in its context.

There are several categories of recognition tests. The most popular ones include:

- yes/no tests: the patient has to say if the item presented to them was also presented in X context;
- multiple-choice tests: the subject is given several items presented to them and that then appear among other items that were initially absent; they have to find the correct ones.

These tests are not as simple as they seem. Here's an example to illustrate this:

For this experiment, select 10 people and read the following text to them:

"It is advisable to eat apples, pears, bananas and kiwis, which are quite sugary, as often as possible. As such, you will have no trouble including them in young children's diet. It is important to be careful with strawberries and grapes, however, as these can cause allergies.

Fortunately, the same is not true for raspberries, apricots, papayas, mangos and peaches. Eating them as part of a meal at least five times a day improves the functioning of the digestive system, while storing up reserves of vitamins. They are equally recommended for adults and children."

Then ask the participants to identify the word or words they didn't hear in the following list:

- apples;
- pears;
- kiwis;
- bananas;
- strawberries;
- grapes;
- fruits ;

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- ➔ raspberries;
- ➔ cherries;
- ➔ apricots;
- ➔ peaches;
- ➔ papayas;
- ➔ mangos;
- ➔ vegetables.

There is a 100% chance that all the participants will give the word “vegetables” as the odd one out. The most attentive will also notice that the word “fruit” was not included, but only a small minority (probably 5% to 10% of the participants). It is almost certain that 99.99% of the participants will overlook the word “cherries”.

This is a recognition test.

Indirect techniques

For these tests, the patient is not required to remember a particular piece of information. Very often, they are asked to analyze the situation and offer a personal judgement.

Two methods stand out from the rest:

- ➔ the *savings* method;
- ➔ the *reminding* method.

✦ The *savings* method

This technique was developed by Hermann Ebbinghaus in the 19th century to analyze semantic memory. He sought to understand how many attempts were necessary to retain identical items if learning was staggered in time. The experiment unfolds as follows.

The subject undertakes two separate phases of learning. The aim is to analyze the number of repetitions required to memorize items during the first phase and during the second. If they are identical for both phases, this means the patient has not retained any memory of the first phase of learning. If they have managed to assimilate even just some of the items presented the first time, learning will be quicker during the second phase because the material is exactly the same.

Hermann Ebbinghaus developed a relatively simple formula to evaluate this memorization index:

$$S\% = (S_a - S_r) / S_r \times 100$$

S represents the percentage of savings.

S_a represents the number of attempts that were made prior to full assimilation of the programme presented to the patient during the first phase of learning.

S_r represents the same value as S_a, but for the second phase of learning.

This method offers the advantage of being universal.

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In most cases, the tests used for children have to then be adapted to meet adults' needs. This is not the case here. It can be used to assess adults just as it can be used to test children. It goes without saying that the items to retain will be different, but the methodology remains the same.

★ Reminding method

The principle of reminding recalls that of the direct test with cues. In this case, the patient also receives an anchor to help them recall information. There are several methods of reminding, the best-known and most popular of which include:

- ➔ the Grober and Buschke test;
- ➔ the Dubois test (or the five-word test).

★ Grober and Buschke test

This test is also known as the *free and cued selective reminding test*, according to Grober and Buschke's paradigm. It is used to assess episodic memory. It is relatively simple to conduct and is used for patients who have cognitive impairments. It helps to immediately identify any worsening of the patient's condition. The Grober and Buschke test is only useful if the subject's state of cognitive degeneration is mild. It sometimes helps to detect Alzheimer's disease in the first stage of the condition.

The test is made up of several words divided into several categories. In the initial, traditional version, there are 16 words and 4 semantic categories. The test is based on the subject's encoding abilities. They are invited to memorize the words given to them. They are given cues during the memorization phase, and also during the retrieval phase. The anchors are the same in both cases.

The subject is asked to remember the words from different categories, for example:

Sparrow	Dentist	Cardigan	Melon
Gooseberry	Harp	Daffodil	Shirt
Geography	Celery	Herring	Palm tree
Judo	Measles	Piano	Brass

They are presented with two lists of 16 words in total during the encoding phase. The first is called the *core list* and the second is the *parallel list*. The latter contains different items (words) to those on the core list, but that can be classified in the same categories as those on the first list.

During the retrieval phase, the subject is given a third list: it contains a mix of words that are totally different to those on the first two lists, as well as those the subject was asked to learn. This list is made up of 16 words from the lists they have learnt, 16 words that are *neutral distractors* and 16 words that are *semantic distractors*.

The words are presented on a sheet in groups of four. Learning is strictly regulated. The specialist shows the subject the different sheets, and immediately gives them the cues that will serve as anchors for the subsequent recall. Let's take an example with two sheets:

First sheet	Second sheet
Cardigan	Melon

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Daffodil	Shirt
Herring	Palm tree
Piano	Brass

The examiner might ask the subject if they know the name of a musical instrument, a fish, a flower, etc. Thus, the individual retains each word by giving it a precise category.

The learning phase takes place in three steps: ICR (immediate cued recall), the distraction phase and the FR and CR (FR: free recall; CR: cued recall) phases.

➔ ICR phase

The subject is asked: “Do you remember the name of the item of clothing on this list?”, “What name of a plant is on this list?”, etc. The person gets three attempts for each sheet. They can take as much time as they need, within reason of course.

➔ Distraction phase

After successfully recalling the items on all the sheets, the examiner has to distract the subject for a while, for up to 20 seconds. There are various options: “Now close your eyes and relax for a few seconds before we start again”, “We’re going to count backwards from 10 to 1 before we start again”, etc. The key is to distract the subject for a while.

➔ FR and CR phases

In these phases, all the tests are timed. First, the subject is asked to recall as many words as they can in 2 minutes. The order and category do not matter. What matters is to accurately reproduce all the words from the four lists (or at least most of the words). This is the free recall phase.

After **the distraction phase**, nearly all patients will not be able to remember all the words. It’s also highly likely that they will make mistakes with words they think they have learnt, but that perhaps weren’t on the core list.

The **CR phase** is based on these errors and omissions. The subject is given a cue, but the recall time is limited to 10 seconds per word. Note that the examiner needs to distract the patient between the FR and CR phases. The list of words can be longer depending on the subject’s sociocultural level.

The retrieval phase begins immediately after the cued recall in the learning phase. As mentioned previously, the items from the four sheets will be mixed with 32 unfamiliar items. This is a simple recognition test during which the subject has to answer with only yes or no: yes if they recognize the word, or no if the word was not on the initial sheets.

Despite all the advantages, this test presented a significant disadvantage: offering the subject category-related anchors hindered the evaluation of spontaneous encoding. To address this issue, a new test intended to evaluate periodic memory was developed: the double memory test, which involves not 16 items but rather 64, sorted into 16 categories.

★ Dubois test (or five-word test)

This test assesses verbal episodic memory using five words belonging to different semantic categories. The words are learnt using semantic cues.

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If the words are retrieved successfully using the cues, we can deduce that the memory capacity was maintained but that there was a difficulty regarding spontaneous activation of the recall strategies: this situation is typically observed in normal, anxious and depressive subjects, as well as in patients with frontal-subcortical disorders.

On the other hand, if recall was unsuccessful in spite of having cues, we can conclude that the memorization process was structurally insufficient: this situation is observed when there is a hippocampal defect.

Indeed, this test is used very often in clinical practice to identify Alzheimer's disease. However, it is not developed enough to identify neurological conditions or a wide range of memory disorders.

The process is relatively simple.

The subject is presented with 5 words they have to read in an audible and intelligible voice and remember. Each of the items belongs to a category of which the subject is unaware.

The examiner might have the following list, for example:

Lion	= Animal
Cactus	= Plant
Underpants	= Item of clothing
Milk	= Drink
Harp	= Musical instrument

The patient, on the other hand, will have the following list:

Harp
Milk
Underpants
Cactus
Lion

Two recall phases follow. The first is an understanding phase during which the examiner asks the patient to name, for example, the drink, the animal, and so on. Then comes the *immediate recall of encoding* phase. After covering the list, the subject will first be asked to freely recall all the words on the list, and then they will be given the name of the category and will have to remember the associated item.

The individual gets 1 point for every correct answer. In total, they should get a score of 10 out of 10. In the event of a mistake or if they are unable to remember a word, the examiner will show them the list again before restarting the process outlined above. The aim is to enable them to remember all the words.

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Like for the preceding test, a distraction phase follows, during which the examiner needs to divert the patient's attention for a few seconds. This may involve counting backwards, a quick assessment of the patient's spatiotemporal faculties, or something else.

The final step involves delayed recall, like that in the free recall/cued recall phase in the previous test. The difference is that there is no gap between the two processes. The free recall phase is followed immediately by the cued recall phase. Each correct word gets 2 points.

The result of the test is the sum of two totals: the total for the delayed recall + the total for the immediate recall of encoding.

$$S = T1 + T2$$

S: Overall score for the test

T1: Total for immediate recall of encoding

T2: Total for delayed recall

Any total score higher than 16 is normal. Anything below this clearly indicates that the subject has impaired memory.

Memory improvement techniques

There are a vast range of options to choose from, but to gain a better understanding of them, we will classify them.

★ Use all the sense organs

It is difficult to imagine memorizing a lesson on organic chemistry in any way other than by reading it and trying to recite it. However, this approach is more difficult by far than if you tried to sing it back, for example. The more sense organs involved in the encoding phase, the easier and more effective the memorization process will be. There is no single go-to artistic method: music, art, dance and writing can all be used. It all depends solely on the subject's personal preferences.

Thus, you will remember a text more quickly by:

- reciting it like a poem or retelling the text like a story;
- by mapping it out;
- singing it;
- writing it out again by hand;
- dancing;
- connecting the information with colors, scents, sounds and tastes;
- using all the above options.

In the case of dancing, we're not talking about reading the text while moving about senselessly, of course. It's about structuring the text to find the key parts that will act as anchors. These anchors are what the movements should be based on. It is not so much about dancing as it is about an exploration during which the subject makes several stops to memorize the information.

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Overall, it is beneficial to use art therapy from time to time. Music therapy, for example, helps patients with Alzheimer's disease to avoid losing contact with their environment and slows the progression of the disease slightly.

🌟 Improve your observation skills as much as possible

It's impossible to memorize things if you are unable to observe. Very often, when entering a room, the subject's gaze will linger on the largest and most colorful objects – in short, the things that jump out at them. However, it is preferable to learn to be attentive to objects or cues that no one or very few people notice.

➔ Example:



Look at or get someone to look at the photo above for 10 seconds, then cover it over and try to list all the objects that caught your attention.

Did you notice the four lamps above the table?

Training needs to be permanent; it is not time-consuming and can be done anywhere. You will see results quickly. After 2 or 3 months, your memory will be used for spotting and recording the smallest of details.

The same training is appropriate for photos. It is advisable to get into the habit of analyzing the details in photos meticulously, then trying to remember the different elements after covering up the photo.

🌟 Avoid any forms of distraction during the encoding or recall phases

Encoding is the most sensitive phase in the process. Poor encoding will lead to storage errors and, as a result, retrieval of information will be defective. During retrieval, you sometimes need to take your time. If a piece of information doesn't come to mind straight away, simply focus your full attention on the subject or the desired information and wait a few minutes.

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★ Step out of your comfort zone

A life that is completely organized and punctuated with tedious tasks and activities does not help to improve the memory. In order to develop, the brain needs to be permanently awake. This is only possible when you learn new things frequently.

Learning is not limited solely to academic activities. Learning to play an instrument, knitting, sewing, painting, discovering new languages, and getting involved in a new sporting, physical or intellectual activity (puzzles, dominos, chess, sudoku, crosswords, etc.) are just a few options to activate the brain's physiological processes.

★ Avoid constant pessimism

Some individuals have a better memory capacity than others. However, it's important not to feel downhearted if you realize that you remember names or numbers less well than other people. Depressive and negative states always have a harmful impact on the memorization process. Even if you notice that your memory is failing, the best thing to do is to train and improve it rather than feel down and depressed about it.

★ Use mnemonics

Mnemonics help to draw on the brain's resources as much as possible to improve memory capacity.

➔ Make associations

Raisins, watermelons, mangos, oranges, strawberries, pears, apricots, peaches, cherries: no child will refuse to try these fruits. However, it's unlikely you will convince them to try a lemon, even if it's covered with sugar. Despite their age, children have already made associations. Strawberries, oranges, watermelons and the other fruits mentioned above are associated with being 'sweet' and pleasant to eat as a result. As lemons are not found on this list, it will be impossible to get a child to eat one, even if they are half asleep.

Association makes it possible to create vivid images in the brain that stay there. The associations that are made are individual and based on each individual's experience and lifestyle. The image with which the information is associated needs to be striking enough so that it remains imprinted in the memory forever. When we talk about fires, for example, the visual association is quite emotive: extreme suffering for those who experience it, screams and death.

The principle of association works with text and figures alike. It will not be easy to remember the sequence of numbers 27510061419411631391208, even in two minutes, unless you recite it non-stop. However, we can make it easier to memorize by splitting it up and associating several numbers with events in everyday life.

For example:

2 = house number

75 = my father's age

10 = my son's birthday

06 = month when I was born

14 = my daughter's age

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19 = my son's age

41 = my age

16 = number of years I've been married

31 = my youngest brother's age

39 = my second younger brother's age

12 = day I was born

08 = day my son was born

The number is the same and it is still just as complex. However, by associating an event with each number, not only will you remember it more quickly, but you will also not be likely to forget it. This approach involves both association and grouping. Those who enjoy casino games very often remember numbers by picturing card games. Sports fans will use the numbers of their favorite players; the approach varies with the individual.

★ Think about acronyms

CIGAR! For most people, this is simply something harmful to the health written in capitals. However, for those who work in aviation, it is an extremely important acronym. It is used to perform the final checks of a plane before take-off.

C for controls

I for instruments

G for gas

A for attitude (trim and flaps)

R for run-up

"Prior to take-off, check the controls (C), make sure the instruments (I) are set, check the gas (G) and that the fuel is on the proper tank and the pump is on, check the attitude (flaps and trims set) perform the runup (R) check with the magnetos." This text provides exactly the same information as the acronym, but it is much more difficult to remember.

The acronym selected needs to be simple but punchy and bring together all the important information from the text you are trying to remember. Returning to the acronym CIGAR, it is enough to understand that the action is to be carried through to the end, and each letter acts as part of the common thread.

Certain well-known acronyms have ultimately become words and few people remember that they were acronyms to begin with. This is true for radar, for example. The expression RADAR is the abbreviation of *Radio Detection And Ranging*. The same is true for LASER, which is simply the abbreviation of *Light Amplification by Stimulated Emission of Radiation*.

★ Awaken your poetic spirit

The presence of anchors makes it easier to memorize information and, in this way, rhymes are excellent tools. We all remember the little song children are taught to help them learn to count to 10.

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1, 2,

Buckle my shoe

3, 4,

Open the door

5, 6,

Pick up sticks

7, 8,

Lay them straight

9, 10,

A good, fat hen

Repeating it just once is enough to remember the information and, even if the child forgets it, they will quickly remember the missing number or numbers, thanks to the rhyme.

★ Think about acrostics

The information you want to remember may be minimal but quite complex to keep in your mind. As an example, let's take Mendeleev's periodic table. It is made up of a few letters: nothing complex at first glance, apart from the fact that they have to be remembered in a very strict order.

Na, Mg, Al, Si, P, S, Cl, Ar, the elements in the third line of the table, can be retained more quickly using the acrostic *Native Magpies Always Sit Peacefully Searching Clear Areas*.

You have probably also heard the term FANBOYS, which is an acrostic to help to remember the conjunctions For, And, Nor, But, Or, Yet and So.

★ Speak out loud to activate the memory

This is one of the methods to use for maximal operation of the sense organs. It's one thing to hear a name or a piece of information; you may forget it just a few seconds after having heard it. However, if you repeat the information in question immediately, the encoding process is quicker and more effective.

For example, imagine you've just met someone. They introduce themselves using their name, Matthew, but it's highly likely that you will have forgotten this information a few minutes later. To make sure you don't forget his name, at least in the coming minutes, simply repeat the information: *"Matthew! Very pleased to meet you, Matthew."*

★ Use mental imagery

Using mental imagery is particularly effective if it requires the subject to reach a certain level of relaxation. It encourages them to use their imagination as much as possible. Thus, the person reads a piece of information and pictures a whole story based around it in their mind. It goes without saying that the latter mustn't just be a "tale" devoid of meaning. It's important to read the information to be retained, then create a virtual world in which all the important information can be categorized.

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This is roughly what the famous loci (“place” in Latin) method is based on. This is a very old technique that dates back to Ancient Greece. It involves picturing a long road dotted with important places. All these locations correspond to the important information. Thus, by remembering the route, the individual will also remember all the information that is to be retained.

✦ Atypical techniques

Adults can use a very effective trick: sexuality. This might sound strange, but we never forget information linked to sex, however complex it might be. Associating the information to be retained with a text with sensual or sexual connotations will help you to remember it quicker.

The second option can be likened to a form of codification. It’s about associating letters with numbers. Eventually, we obtain a sequence of numbers that may be easier to absorb. Moreover, the codification exercise in itself already constitutes an excellent form of memory training.

✦ Lifestyle

Lifestyle has a huge importance on memory capacity. Excessive intake of psychotropic substances, sleeping pills, anti-anxiety medication or alcohol, or a vitamin or micronutrient deficiency, causes memory lapses.

✦ Oxygenate the brain

The brain, whose main function is to manage and control all the body’s functions, consumes an enormous amount of oxygen. Any defect in this area leads to a loss of memory or, worse still, death. The symptoms of hypoxia are memory loss, dizziness, nausea, headaches, behavioral problems and tachycardia. However, these early warning signs are not always noticeable, especially when the defect is relatively mild.

How can we oxygenate the brain to its optimal level? First, we can achieve this by leading an active lifestyle; for example, by walking for 1 to 2 hours a day. Sporting activities improve respiration in general and, as a result, the level of oxygen in the body. Second, it is important to take the time to breathe every now and then. Long periods of deep breathing while memorizing information help to store it.

✦ Eat more healthily

A good diet improves memory capacity. Thus, the following food groups should be prioritized:

➔ Foods with a low glycemic index:

- ❖ pulses: green lentils, red lentils, chickpeas, peas, flageolets, haricot beans, etc.,
- ❖ vegetables (all vegetables have a very low GI),
- ❖ nuts: pecan nuts, cashews, almonds, pistachios, macadamia nuts, etc.,
- ❖ fruits: apricots, melon, papaya, cherries, bananas, pineapples, apples, grapefruit, kiwis, pears, avocados, oranges,
- ❖ whole grains: oats, spelt, buckwheat, sorghum, basmati rice, quinoa, millet, corn, etc.,
- ❖ dairy products: yoghurt, whole milk, skimmed milk, plain cottage cheese,
- ❖ tofu (and many soy-based foods),

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- ❖ dark chocolate (70% minimum cocoa),
- ❖ wholegrain pasta;

- ➔ Eggs;
- ➔ Oily fish: herring, tuna, sardines, salmon, mackerel, etc.;
- ➔ Berries: strawberries, blueberries, lingonberries, blackberries, raspberries, currants, Goji berries, cranberries, etc.

Herbs and spices like turmeric and ginkgo biloba can also be added to this list. Consumption of foods high in vitamins B, A, C and E is also recommended.

Conclusion

Memory, and the memorization process along with it, is a brain mechanism that has taken a long time to be understood. We have had to wait for the advent of medical imaging to be able to detect the areas of the brain and the parts of the central nervous system that are involved in the memorization and recall processes.

This greater understanding of memory, achieved by means of tests that enable us to assess it, is helpful today in cases of neurodegenerative diseases and other conditions in which the memory may be affected. Once we have a better understanding of an area, we can also take preventative action.

It is possible to maintain the memory at any age in order to prevent potential problems or improve the memory capacity with a view to learning better. We will take a closer look at this in the next module.