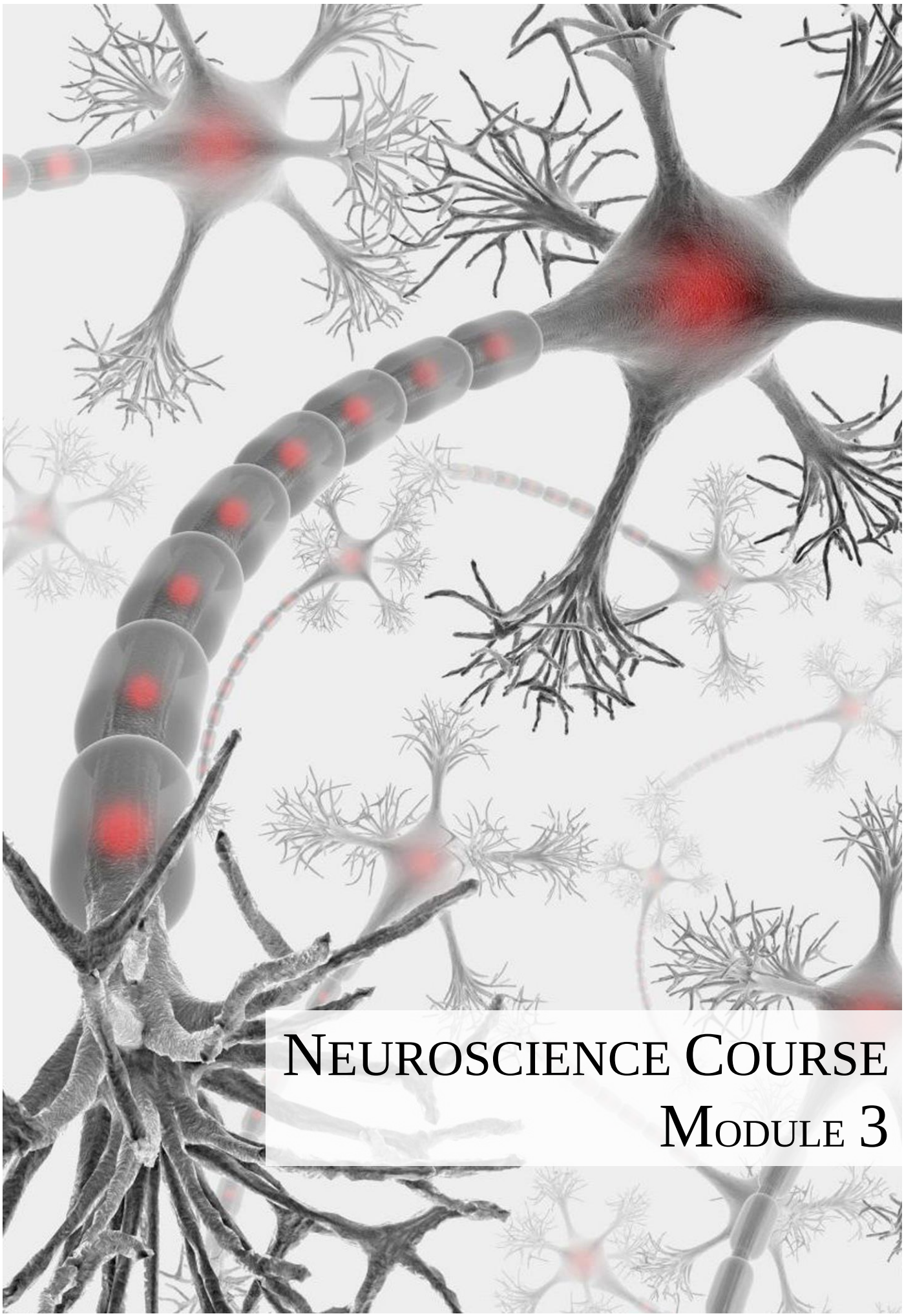


Neuroscience Course

Module 3

Module 3 :
LEARNING

Memory and learning! Life and the evolution of all species rest on these two pillars. From birth, the acquisition of new knowledge is vital, as without it, human beings could not move forward. We learn to walk, talk, use different tools and utensils, etc. In fact, whether we want to or not, we learn from birth until death, and these two processes are interdependent.

Since the 20th century, several scientists have developed theories and processes that facilitate the mechanisms of memory and learning. In the previous module, we took a closer look at memory, its physiological mechanisms, and ways of assessing and improving it. In this module, we will focus on learning, its mechanisms and the forms it takes. We will also look at how neuroscience can help to improve this process.

Definition of learning

Many people believe that learning is a process that begins after birth. In reality however, it starts long before the baby comes into the world. The future baby learns to recognize the people around it during embryonic life. From the sixth month onwards, it reacts to common noises, voices that have become familiar to it, music and its mother's emotions. However, this phase of learning is relatively passive because the future baby's environment is limited and so too is its capacity for learning.

The situation changes at birth, when the baby finds itself in a highly turbulent environment in which learning becomes a necessity, a form of survival. We discern two perceptions of this process:

- **the neobehaviorist perception**, which involves an acquisition of skills and new information that can develop the subject's skills;
- **the cognitivist perception**, which deals with the modification or evolution of information learnt previously.

The notion of learning must not be seen exclusively from an academic perspective. We are constantly learning every day; this is why learning is not a static process regulated by strict rules.

Learning is a constructive and active process because it requires the subject to be deeply engaged in order to succeed. It is also a progressive operation because there is a close link between knowledge acquired previously and knowledge that is acquired at a precise moment. It would be unthinkable to learn a foreign language if you could not already express yourself in another language, for example.

Moreover, this process requires good coordination of all the information learnt. As such, it is a long and sometimes difficult operation that needs to consider the subject as a whole: their age, skills and interests.

Hebb's theory

Hebb's theory, also known as the "cell assembly theory" or "Hebb's postulate", was proposed in 1949 by Donald Hebb. This law can be summarized in a few words; the more a neural network is stimulated by a concrete activity, the stronger the connections between the neurons in this circuit will become; as a result, learning will only become easier. This is a free form of learning, without supervision, that offers the brain the scope to correct its mistakes itself in order to ultimately reach a stable state.

This law is expressed using the following formula:

$$w_{ij} = \frac{1}{p} \sum_{k=1}^{p} x_i^k x_j^k$$

W_{ij} represents the weight of the connection between the neurons.

i, *j*, *p* represent the number of models learnt.

x_i^k represents the *k*th input for neuron *i* (as well as neuron *j*).

Overall, the theory is based on a principle of repetition. The seriation of processes is a phenomenon frequently employed by the body. To demonstrate this, we simply need to recall the development of motor skills. Babies do not stand up immediately. Learning starts long before they are able to stand up.

First, the baby needs to learn to keep its head up, then to control its body and turn over on its own in its sleep. Then comes the initiation to mastering the seated position, which comes before the crawling stage, first on the stomach and then on all fours; it is only after all these phases that the baby will try to stand up and then take its first steps. When it comes to walking itself, it will fall many times before finally being able to move normally.

This is not only a repetitive act; the child gradually develops its ability to walk until it achieves perfection. This is a cumulative learning process during which the child absorbs several sequences. We also observe this during language learning and the acquisition of a number of skills.

This theory does have its limits, however. Sequential learning is only possible in certain circumstances. In theory, the repetition of a cumulative process leads to the development of the ability to learn due to the development of the synapse network.

Methods of learning

Learning is a process that involves acquiring knowledge, skills, values and attitudes, through study, teaching or experience. This complex mechanism is made up of several phases. These are:

- the acquisition phase;
- the retention phase;
- the transfer phase.

✪ Acquisition phase

The initial phase is generally considered as the journey for all information, from its perception through the sensory memory to its understanding or representation by the short-term memory. In the field of education, this phase is crucial; this is the stage when the teacher will need to structure

the information transmitted in order to provide the student with the anchors that will help them to absorb it.

The success of this phase is connected to both the student's psychological state and the teacher's professionalism.

The student

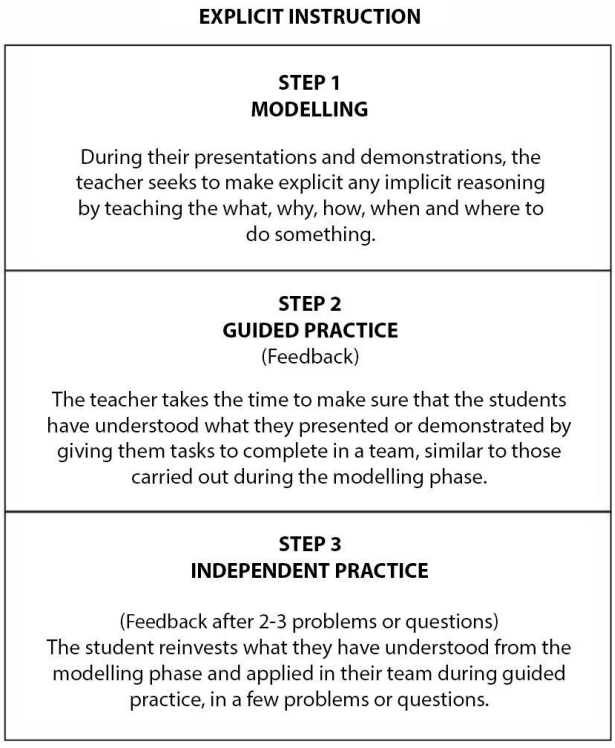
Their state is crucial because all students have different foundations. It is not solely about their psychological state, but also their responsiveness, character, etc. This means that initially, not all students are receptive in the same way. For the acquisition phase to be successful, the teacher needs to draw on each of their students' sensory condition.

The teacher

The teacher has a duty to systematize all the information provided and adapt it to each student's abilities. This approach is complex within a traditional education system. Indeed, to optimize the results, the teacher is obliged to deal primarily with students who are capable of adapting to the traditional, rigorous rules. These rules may lead to an imbalance in the perception and therefore assimilation of the information received.

As such, to ensure each step is successful, the teacher needs to approach representation like an explanatory system to be understood; either to detect the error to be eliminated or the obstacle to be overcome, or to take support on this foundation with a view to promoting understanding and learning in students. To learn is to modify one's representations until one understands and retains the learning object.

The principle of explicit instruction is divided into three categories, as shown in the following figure.



The teacher will take care to explain the material provided in great detail so the students can get an exact idea of the knowledge being transmitted to them.

✪ Retention phase

Once the subject understands and can visualize the information received, they are required to move onto the next phase: assimilation. No learning can take place if the subject is incapable of remembering the knowledge that was transmitted to them. The creation of a memory trace is linked to several factors:

- the individual's capacity;
- previous experience;
- the techniques used;
- prior knowledge.

We may be tempted to consider prior experiences and knowledge as equal. This would be incorrect however, because the two elements are completely different. The subject's prior knowledge is made up solely of the knowledge they have acquired prior to the concepts to retain. Previous experience, on the other hand, represents the way this knowledge was obtained. The following example will shed light on the two cases.

Francis and Albert are both 7 years old. They just had a maths lesson, and neither of them particularly like the subject. Albert has a very strict family that borders on violent, and he always has to prove himself to avoid getting into trouble. The last time he got bad grades, his dad punished him; he fears having to relive those painful moments more than anything.

To help him, his dad teaches him at home. However, the latter is not very patient, and every mistake the child makes is punished with reprimands. To Albert, his father's lessons are an even greater source of stress.

Francis' parents are far from giving their son complete freedom. Like Albert's parents, they push him to only ever get good grades. However, they are aware of their son's weaknesses, and use several techniques to encourage him, one of which has proven quite effective. Francis receives praise and gifts every time his grades improve.

Both children's motivation is the same: one wants to avoid his father's wrath, while the other wants to get what he wants. However, the approach in terms of learning will be different.

From a pedagogical point of view, the retention phase is divided into three steps; objectivation, consolidation and reinvestment.

Objectivation

This step involves putting the individual in a situation of learning attitudes, concepts or strategies to retain. It is a form of grading information during which the subject is asked to sort the information received. They need to retain primarily the information that is of interest, then retain as much of the secondary information as possible. This is a complex task that very often requires the assistance and support of the person transmitting the knowledge.

Consolidation

The next step is that of consolidation. It involves going back over the information stored during the objectivation phase regularly. It is not about performing a radical review. The subject simply does a cursory re-read of the concepts learnt so they remain imprinted in the memory. Consolidation takes place a few hours or days after the beginning of the learning phase. It is a crucial phase because the more the subject goes over these notions, the better chance they will have of storing them in the deep memory.

Reinvestment

This final step takes place a few months or even years after the initial phase of learning. The subject uses it to refresh and retain the information received so they do not forget it. The aim of reinvestment is to retain the concepts learnt for as long as possible. This phase will remain crucial for as long as the subject needs this information. Some concepts, especially if they have been used for a long time, will not disappear.

Whether learning is successful or not in general depends on the ability to manage these three phases perfectly.

Transfer phase

This relates to the ability to use the concepts learnt in a context that is different to the one in which they were learnt. This is the very aim of learning. There are two forms of transfer:

- vertical transfer, which is defined as the ability to use something that was learnt in a simple context in a more complex context;
- horizontal transfer, which is defined as the ability to generalize something that was learnt in an initial context to new contexts.

The transfer phase is not linked to a memory-related activity. It is a form of adaptation of the information learnt to everyday life. It can also be seen as a practical application of the concepts learnt. The transfer phase is not obligatory during the learning process, but it facilitates it considerably. It is a form of subsequent learning.

Let's use an example to illustrate this phase. An ice skater will find it much easier to learn to use in-line skates than someone who has always done traditional roller-skating (with four wheels). This is because the wheels on the first type of skates are aligned like the blade on an ice skate, which will naturally be familiar to the ice skater.

Psychologist Edward Thorndike considered "specific knowledge and skills [to be] crucial elements that form the basis of transfer". However, his vision only partly reflects the true state of affairs. Indeed, he only considered the learner's tasks and ignored their personal characteristics (motivation, capacity for understanding, etc.). Nowadays, we also consider all the learner's experience and knowledge.

However, transfer is far from being a simple task. Recent studies have identified three major difficulties. The first is linked to the 'level of similarity' between the different tasks. The student (or learner) must be able to draw parallels between the concepts learnt and those still to be learnt.

For example, it will be easy for a tennis player to find points of similarity when learning to play ping-pong or badminton. On the other hand, there is no chance of them being able to draw parallels between tennis and boxing. This doesn't mean that it's impossible, but that the two sports have very little in common.

The second difficulty partly incorporates the first, but it only relates to the learner's abilities. Returning to the example above, this means that it does not matter very much if links can be made between tennis, badminton and ping-pong, as the student needs to be able to make them themselves. If the similarities between these different sports are only obvious to the teacher, transfer will be impossible.

The final difficulty takes into consideration the different contexts for learning. Indeed, as surprising as it may seem, we learn more easily in some contexts than others. For example, consider the case of a child who has no difficulty counting their sweets by subtracting, dividing, multiplying or adding, but who struggles to do simpler operations if they are presented in a maths book.

To overcome all these complications, the teacher needs to help the learner understand the information being transmitted. Specialists recommend preparing the student to recontextualize the concepts to be learnt. It is up to the teacher to guide the learner so they perform the transfer.

This role involves deliberately provoking a metacognitive reflection using objectivation in order to facilitate recognition of what is similar from one situation to another, and by preparing students by allowing them to perform several similar tasks.

PHASE 1 **ACQUISITION**
- Explicit instruction + supervision + feedback - Mastery learning - Overlearning: repeated and varied practice that seeks to make the process automatic
PHASE 2 **RETENTION**
- Objectivation - Consolidation: periodic revision over time - Regular reinvestment
PHASE 3 **TRANSFER**
- Planning of learning: structured, ordered, successive and cumulative (vertical transfer) - Enrichment: further opportunities to reinvest learning in various situations (horizontal transfer)
Over the 3 phases **DEVELOPMENT OF METACOGNITION**
- Teaching of cognitive strategies - Pedagogical interventions that support a dynamic view of intelligence

Thorndike, Singley and Anderson state in their work that it is important "to help students to construct an abstract representation of their experiences that transcends the specificity of the initial context of learning".

Overall, transfer is linked to the ability to move from one context to another. The student needs to be able to "decontextualize the learning achieved in the source tasks to transfer it to target tasks, without any support from the instructor".

All these elements lead to the development of metacognition. Metacognition is defined as "the ability to reflect on one's own thoughts, to sensitize, control and manage the different mental processes used in information processing to ensure optimal functioning".

The development of metacognition is the result of both intensive training and deep introspective work. The individual gradually ends up assimilating the useful concepts to perform certain tasks, but also becoming aware of their skills. This leads them to adopt self-reflexive behavior that results in regulation of all the processes involved in information processing.

Thus, it is possible to improve students' capacity for learning by refining the development of their metacognition. To achieve this, the teacher needs to teach them to oversee their work themselves by comparing their learning techniques with other possible processes. The aim is to lead them to take a critical look at their approach and all the available options in order to adopt the technique that will give them the optimal result.

Forms of learning

The classification of forms of learning depends on several factors. In general, there are two main groups:

- associative learning;
- non-associative learning.

Both of these groups are divided into several subcategories.

✪ Associative learning

All teaching techniques that rely on a form of stimulation to teach are described as associative learning. This form of learning occurs through conditioning. Conditioning is the formation of new behavioral patterns (or the acquisition of new knowledge) by means of a stimulus. The subject discovers the concept that is to be retained, then the educator encourages them to associate it with the stimulus.

We distinguish between two forms of learning: classical and instrumental learning.

- Classical learning

It might seem obsolete, but this is the very first form of learning all humans encounter. Let's take the example of potty training a child.

Once the child starts walking, potty training can begin. The mother or father choose a tune and put the child on the potty while humming it so the child goes to the toilet. At first, the child does not pay

attention to this association; this is simply quite a fun game. The child wears a nappy and knows that even if it goes to the toilet in it, someone will change it.

After a few weeks, the situation will change when the child becomes accustomed to hearing this tune just before it is put on the potty. To encourage it to go at any time of day, its parents simply need to hum the tune. The child will perceive this as the signal that it is time to go. It may even be able to hold it in until it hears the tune.

Eventually, it will realize that it is more comfortable to go to the toilet in the potty than in its nappy. Gradually, for lack of sitting on the potty by itself, the child starts to express to its parents that it needs the toilet.

Classical learning is a typically Pavlovian type of conditioning. It is based on the simple principle of the stimulus and the response to this stimulus, and no more. To return to the previous example, the child is taught that it is appropriate to adopt a behavior different to the behavior it is used to by showing what it is desirable to do: toilet = potty.

Adaptation does not always happen quickly. The most difficult thing is to find the appropriate stimulus. In the case of a young child, it might be music like in the previous example, or a sweet that they are given every time they go to the toilet in time using the potty. Associating the success of the process with a sweet will increase the child's motivation. The principle works with all individuals, as long as the appropriate stimulus is identified.

- Instrumental learning

Also known as operant conditioning, this form of learning rests on two basic elements: reinforcement and punishment. Developed by Edward Thorndike and then built on by Frederick Skinner, this form of learning is based on a principle set out by Skinner himself, namely that "human behavior is conditioned by the consequences of the behavior before it takes place".

The concepts of reinforcement/punishment must not be taken at face value. Within the framework of instrumental learning, reinforcement refers to the "consequence of a behavior that makes it more likely that the behavior will be repeated". Punishment, on the other hand, is the "consequence of a behavior that makes it less likely that the behavior will be repeated".

Neither of the two concepts is purely positive or negative. Punishment and reinforcement can have positive or negative connotations. The positive aspect indicates an increase in the stimulus, whereas the negative aspect suggests a decrease in said stimulus.

Thus, we distinguish between four categories of conditioning:

- **Positive reinforcement**: process whereby the probability of frequency of occurrence of a behavior tends to increase as a result of the addition of an appetitive stimulus contingent on the response, for example with the addition of a reward or congratulations.
- **Negative reinforcement**: process whereby the probability of frequency of occurrence of a behavior tends to increase as a result of the removal of an aversive stimulus contingent on the response, for example with the removal of an obligation or a source of pain.

- **Positive punishment**: process whereby the probability of frequency of occurrence of a behavior tends to decrease as a result of the addition of an aversive stimulus or consequence contingent on the target behavior, for example through the addition of an obligation or a source of pain.
- **Negative punishment**: process whereby the probability of frequency of occurrence of a behavior tends to decrease as a result of the removal of an appetitive stimulus, for example with the removal of a privilege or a right.

There are two types of reinforcement tools. The first (primary reinforcers) are those that satisfy the subject's vital needs. One such example is food. The second (secondary reinforcers) become such as a result of prior learning. In this category, we would include things like money (for adults) or toys (for children).

✪ Non-associative learning

It is easy to work out that non-associative learning will be the exact opposite of the previously mentioned concept. No association is made between the stimuli and the behavior. We distinguish two main categories of non-associative learning, namely learning by habituation and learning by sensitization.

Learning by habituation

Habituation is an informal form of learning. The individual does not need a teacher because the learning is passive. The following example illustrates this type of learning.

A family who have lived in a relatively quiet neighborhood for a long time find themselves in a neighborhood where street violence is common. In the first few weeks, all the members of the family are in a state of shock. Their attention is focused on all the acts of violence, even the most insignificant.

However, if they stay in this neighborhood for two, three years or more, the initial shock will no longer be the same. This doesn't mean that they will consider these events as normal; far from it. It isn't even impossible that they will be even more offended by it than they were in the past. However, they will be less sensitive to it and less inclined to pay attention to it.

Habituation means that, by dint of being permanently exposed to a concrete situation, you stop paying attention to it. In a word, habituation could be described as "desensitization".

Learning by sensitization

The below example describes this form of learning clearly.

Mrs. X has been trying to stop her 2-year-old son from touching the iron for a few weeks now. Though she tries to scold and even punish him, nothing works. Overwhelmed, she decides to adopt a different tactic. One day, after finishing the ironing, she unplugs the iron and waits for it to cool down a little. The aim, of course, is for her son not to be seriously burnt.

Thus, she pretends to be distracted, knowing very well that that is all her son is waiting for before he acts, which he does. He rushes to touch the forbidden object, and instantly starts crying. The temperature of the iron was high enough to hurt him, but not enough to burn him. A few days later, Mrs. X does the ironing again, and this time her son makes sure to avoid the iron. He even refuses to approach his mother while she is holding it.

For a long time, the child was unaffected by all the forms of learning his mother attempted. It ended up taking a 'traumatic' event for him to finally understand; his mother was no longer obliged to explain why he shouldn't touch the iron. Thus, sensitization involves an increase in the response to a stimulus after exposure to an intense or painful stimulus.

The sensitization process can be a one-off, like in this example, but it is very often repeated. If learning takes place in a sustained manner, the subject will be more receptive to the stimulus than during previous experiments.

Other forms of learning

The categorization of types of learning also depends on the pedagogical approach adopted by the teacher. As such, there are just as many forms of learning as there are processes of learning. These include:

- learning through imitation;
- constructivist learning;
- learning through transmission of knowledge;
- cognitivist learning;
- learning through research and experimentation;
- learning through guided actions.

✪ Learning through imitation

This is without doubt one of the oldest forms of learning. It is also universal. Both humans and animals learn through imitation, by copying others. It is an informal and primarily permanent means of learning. We imitate those around us from birth to death.

This form of learning offers one huge advantage: the subject never feels like they are having to engage themselves, so much so that the process happens naturally, without any stress. However, this process also poses a considerable disadvantage: the subject may imitate negative attitudes as much as they do positive information and behavior. When this form of learning is selected within the framework of an educational policy, the teacher needs to ensure that the student only copies the useful elements and information.

✪ Constructivist learning

Developed in 1964 by Jean Piaget, this theory is based on the principle that "knowledge is developed by the learner on the basis of a mental activity". As a result, "by reflecting on our experiences, we build and develop our own vision of the world in which we live".

This theory "emphasizes the fact that the cognitive activities and capacities inherent to each subject allow them to understand and grasp the realities that surround them. Thus, someone who is confronted with a given situation or problem will be required to mobilize a certain number of cognitive structures, known as 'operational schemes'. From there, the person can either incorporate the information perceived within their cognitive structure (assimilation) or modify their cognitive structure in order to incorporate the new elements generated by the situation (accommodation)".

This approach is interesting because the teacher encourages the student to analyze and understand the meaning of the concepts they are learning. Thus, the student is not required to learn all the information by heart. Rather, they are required to interpret it based on their own perception and retain the fundamentals of what they were taught. This type of learning is not therefore based on isolated cases, as it does not give an exact idea of the bigger picture.

This approach is challenging for the teacher, who is required to know and understand the 'inner world' of each of their students in order to facilitate the learning process. By encouraging the student to grasp the deeper meaning of the information that is transmitted to them, learning makes the use of standardized tests obsolete. Indeed, the latter will not be able to assess the student's actual knowledge perfectly.

Constructivist learning is indisputably one of the most effective forms of learning. Indeed, one of the most common reasons for failure in learning is the lack of understanding of the concepts being taught. For example, it does not matter how many times you try to explain to someone how the heart functions, as if they are unable to envision the process mentally, the most they will be able to do is recite the text describing this phenomenon word for word.

✪ Cognitivist learning

Starting from knowledge acquired previously and adopting a more practical and functional form of learning forms the foundation of functional learning. Cognitive learning aims to make use of all the individual's ways of perceiving. Célestin Freinet explained the principle by stating: "[Knowledge] acquisition does not take place as one sometimes believes, by the study of rules and laws, but by experience. To study these rules and laws in [language], in art, in mathematics, in science, is to place the cart before the horse."

Cognitive learning involves a reassessment of the roles of teacher and student. The former is no longer just a being who passes on information; they become more like a guide. In the same vein, the student is no longer just a receiver of information. They become an actor who participates actively in the learning process.

In fact, cognitive learning partially adopts the principle of the Socratic method. This states that true knowledge can only be acquired through reflection and interactions between the teacher and student. It is therefore up to the teacher to invite their student to analyze all the information received and, if necessary, take a critical look at it.

✪ Learning through research and experimentation

This is learning by trial and error because the individual only discovers new information after conducting a test (or several) or experiment. This is the most attractive form of learning because the individual does not feel oppressed during the process. Research forms the basis of this type of learning, and it has the distinction of arousing curiosity.

This type of learning offers many advantages. First, the information retained is never (or at least very rarely) forgotten. Second, the individual has an absolute mastery of all the information learnt. Finally, they will not have any difficulty passing it on to a third party.

✪ Learning through guided actions

This type of learning is still described as “behaviorist”. Learning through guided actions is defined as “a lasting change in behavior resulting from the consequence of particular training”. The teaching involved in this type of learning is primarily based on a contractual arrangement for the subject and the objectives to be achieved.

In fact, it draws partly on the principle of instrumental learning. The teachers assume the position of transmitters. Their role involves transmitting information to students and helping them to absorb the concepts. The latter act as recipients, who receive, decode and store. We can describe it as learning through trial and error regarding the consequences of the answer given: quiz, tests, gap-filling exercises, simulators, etc.

This form of learning proposes two approaches: that taken by B. F. Skinner described earlier in the section on instrumental learning and that taken by Benjamin Bloom. The approach taken by the latter is still described as “learning through objectives”. It is based on the following principles:

- The material to be taught is divided into a series of short elements so the information can be consolidated as quickly as possible.
- The content starts from the simplest level and the difficulty level increases gradually to promote error-free learning.
- The content is presented in the form of a linear sequence, but each individual can proceed at their own pace, which is consistent with individualization of teaching.
- Positive reinforcement (through encouragement, etc.) is promoted and must be given as quickly as possible. Experimental studies have shown that the shorter the amount of time is between the answer to be given and the reinforcement, the better the final performance is.

This technique reached the height of its popularity in the 1970s and remains popular to this day. This is partly due to the fact that it makes it possible to set precise pedagogical objectives that will be reached gradually.

✪ Learning through transmission of knowledge

In general, learning almost always involves transmission of knowledge. Usually, however, the student takes an active role in the process, at least in part. This is not the case here. The learning process is primarily receptive. No special teaching technique is used. The student’s sole task is to absorb all the information transmitted by the teacher. In addition, the teacher is not obliged to help them; they simply set out the concepts required.

This is the oldest form of learning, but also the most complex because the student is left to their fate. If they have excellent foundations, feel truly drawn to the material that is being taught or have enough time to absorb all the information, everything will work out well. If not, it is not uncommon for students to fall behind, have difficulty understanding or simply end up hating everything to do with the discipline.

Pedagogical approaches

In this section, we will describe some pedagogical approaches that will help students to devise their own exercises and thus improve their learning.

✪ Repetitive exercises

Repetition is the mother of science and also the foundation of learning through guided actions. This does not mean that repetitive exercises are solely the preserve of this form of learning. No learning is possible unless an automation system and a system for maintaining the information received have been implemented.

Neither the onset of automatic reflexes nor maintenance of information are possible without repetition. As such, no form of learning can bypass repetitive exercises. However, some forms of learning prioritize it more than others.

Repetitive exercises are effective in certain conditions:

- consolidation of different automated reflexes;
- consolidation of procedural knowledge;
- improvement of memory skills.

This technique (use of repetitive exercises) offers many advantages for both students and teachers. However, it also prevents various disadvantages.

Advantages for the student

First, the student can learn calmly, at a certain pace. Then, if exercises are devised and applied correctly, the student gains a substantial degree of autonomy. Lastly, experience and automated reflexes are acquired without great difficulty. Furthermore, information is assimilated quite rapidly, which allows the student to be fully involved in other equally important tasks.

Advantages for the teacher

The greatest advantage for the teacher is that it allows them to free up enough time to focus on other tasks. As a result, they have more time to supervise and help their students.

Disadvantages for the student

The first disadvantage is linked to the teacher's skills. Indeed, the exercises will be beneficial for the student as long as the teacher varies them. If they do not, the student will not make progress. The exercises must also be precise and completely error-free; otherwise, the error or errors will become automatic reflexes that the student will struggle to shake off later.

Repetitive exercises are only effective for absorbing exact, immutable concepts. If the information demands some reflection and personal analysis on the part of the student, such exercises will be detrimental. Indeed, restricting oneself to simple repetition of information limits the student's analytical capacities. Ultimately, the student will only remember the information in the short term. If these concepts are not useful to them in the future, they will soon be forgotten.

Disadvantages for the teacher

On one hand, devising repetitive exercises that are both interesting and truly useful requires a huge amount of work from the teacher. On the other hand, the teacher will always have to go back over the same concepts, as otherwise the students are likely to forget them.

Oral presentation

A presentation is the ideal exercise to encourage students to reflect. It is not about constantly going over concepts that they do not always understand. In each individual case, the teacher limits themselves to providing a theme and, ultimately, a few outlines to which the student will need to pay attention. The student will need to carry out research on their own and find all the important information. They will also need to present all the elements in an explicit, ordered manner.

The success of an oral presentation lies in the student's ability to plan. Before presenting in front of an audience, they need to:

- establish a concrete plan with four main ideas at the most;
- consider the audience's expectations and adapt their plan accordingly;
- prepare the presentation while carefully managing the allotted time;
- deliver the presentation.

This activity offers many advantages, both for the student and teacher.

For the student

Any presentation encourages the student to conduct research. They transition from a passive stage, during which they are content to record the information passed on, to an active stage when they are required to design a lesson. The student learns to use all the sources of information in an optimal manner. In the long run, this will help them to review and improve the learning process.

Doing a presentation motivates the student to become independent. The concepts learnt during the process will be remembered for a very long time. Furthermore, the student can improve their oral skills, and ultimately overcome any shyness. On top of that, the student discovers the difficulties the teacher has to face; this may lead them to be more attentive as a result.

For the teacher

For the teacher, this is the most effective way of introducing students to the concept of autonomy, as well as helping them to remember the concepts to be retained in the long term. This option also helps to free up time for the teacher because their role in this process is limited to supervising the students' work.

Presentations are one of the few exercises that do not come with any disadvantages. Indeed, if the student has gained a good grasp of the subject and manages to put together a cogent lesson, they will remember its content for a long time, and if they make any mistakes, it will be easy for them to see their errors, understand why their approach was wrong and, of course, rectify it. In both cases, they will retain the precise information.

✪ Group discussion

The effectiveness of this exercise stems from the fact that the student does not feel like they are learning and therefore does not feel any stress. Group discussion requires careful planning. The teacher needs to set out the guidelines beforehand and make sure that the group members stick to them.

Moreover, the students involved in the discussion need to have a grasp of at least the basic concepts of the subject in question. This is both an advantage and a disadvantage. The advantage comes from the fact that each participant will need to prepare for the discussion so as not to feel confused. However, the level of preparation will not necessarily be the same. As such, some of the group members may feel left out of the group.

Nevertheless, group discussion remains a very useful exercise as long as it takes place in a medium-sized group. In a small group, the discussion will not be very interesting. If the group is very large, the discussion will only be able to take place between a few participants, generally those who are the most informed about the subject; the rest of the members will opt out voluntarily.

✪ Role-play

This exercise is ideal for preschoolers and young children. In some senses, it draws on some principles of group discussion, with the exception that each member plays a precise role. Like in the previous case, this exercise has the advantage of helping the participant to learn unwittingly. In this case, the situation is even more interesting because each member of the group sees the process as a game. The process of memorizing concepts therefore happens more quickly than if the individual had to absorb all the concepts taught by themselves.

Adults are just as receptive to play as children, so you shouldn't be afraid to use this kind of exercise with them. The key is for the role-play to be adapted to the subject being taught and the group's needs.

✪ Simulation

Medicine, languages, IT and aviation are all areas where simulation is regularly used as a learning technique. Simulation can be defined as the "reproduction of a situation that constitutes a simplified but accurate model of a reality". Overall, it helps the teacher to condition students by putting them in a situation that is as close as possible to a real situation that they might find themselves in.

The effectiveness of simulation lies in the fact that it helps students to analyze the concepts learnt from all angles. Indeed, even the 'sterilized' environment in which they find themselves will present them with unexpected situations that will lead them to rethink or reassess each of their actions. The student and teacher both benefit from it: the former can put the theoretical information they learn into practice, and the latter can make sure that the student has truly understood and absorbed all the concepts communicated to them.

✪ Research

This involves studying one or two important concepts in depth. The research work never extends to a theme in a broad sense. It is always limited to a specific subject that the student needs to analyze and study in depth. The most significant advantage of this method is the fact that it encourages the

student to approach new concepts. To be successful in their research work, they will need to think outside the box and then be able to present their new knowledge in a concise and precise manner.

There are two approaches that can be taken to research. The first is guided research. The teacher analyses the student's weaknesses in a specific area, then suggests that they explore it by themselves, drawing solely on raw, basic data. It is not in any way about making a discovery. The student's sole task is to take another look at the subject themselves without considering secondary information passed on by the teacher. They reassess the basic concept by rewriting the lesson according to their own vision.

The second approach concerns research work. Here, the student can start either from raw or more detailed concepts. In both cases, the research carried out ensures that the subject examined is stored in the memory for a very long time. This is its greatest advantage.

Educational exercises are not restricted to those mentioned above. You can also add:

- laboratory work: when students, under the supervision of their teacher, seek to establish the causes and effects of phenomena, as well as their properties and nature;
- play: this is the first educational exercise individuals experience, but also the most effective, regardless of age. Play can recreate a highly realistic environment that will place the student in conditions similar to those of simulation.

Improving learning through neuroscience

Neuroscience occupies an increasingly important role in modern society, and it is not surprising that we tend to apply it in many areas. Many people urge us to consider neuroscience in order to improve education. It is impossible to understand the learning process itself without also understanding how the brain functions. However, one question remains: do we need to rethink education or the principles of learning?

✪ Education and learning are not the same

There is a strong temptation to place these two terms on an equal footing, but to do so would be wrong. All training and educational practices draw on different principles of learning, but education takes other factors into consideration.

Education is a systematic system of teachings and training. New concepts can only be acquired through a teacher. Even in the case of remote learning, the role of the teacher does not disappear. Even though the student studies primarily on their own, they are controlled and guided by a teacher.

Learning is far more informal. It is sometimes based on the individual's experience or skills and sometimes happens naturally, without any effort. Knowledge can be acquired with or without the help of a teacher. Moreover, the information learnt can come from one or several sources at once. The educational process is time-bound, unlike learning. Humans never stop learning, as long as they want to do it.

Does neuroscience occupy a position in both processes? The answer is yes, without a doubt. In the framework of education, it can be used to hone the techniques used and maximize students' chances. With regard to learning, the key term when referring to neuroscience is 'neuroplasticity'.

✪ Neuroplasticity

Almost all mammals manage to move around in the first few hours after birth. Kittens, chicks, puppies and many others gain almost complete autonomy after just a few days. But why do things happen differently with humans? Why do humans need around 6 to 7 months before they start to move around, and almost a year before they finally learn to walk?

The answer is simple: humans are one of the few mammals whose brain is not mature at birth. What's more, their brain does not finish maturing until they reach their thirties. So, what is neuroplasticity and what influence does it have on the learning process?

The concept is more complex than it appears in popular scientific articles. Neuroplasticity is very often defined as "all the changes the adult brain goes through over the course of life: variation in the number or nature of the neurons and synapses, and indeed the person's behavior". From the perspective of learning, neuroplasticity can also be considered as the brain's ability to be shaped according to the events it lives through.

The nervous system is not static; it reacts to every new experience by adapting to the conditions to which it is subjected. The following example was an experiment conducted in the 1990s.

Electrodes were placed in the somatosensory cerebral cortex of adult monkeys to measure the activity of different subregions of this cortex. These electrodes made it possible to identify the zones that were "activated" when a finger felt something. The researchers began by setting out the sensory map at the start of the experiment to show which subregion was activated when the animal used finger "1", and the same for fingers "2", "3", "4" and "5".

After this, the monkey had to do exercises each day that mainly required fingers "2" and "3" and sometimes "4". After three months of exercises, the sensory map had changed; the scope of the subregions associated with fingers "1" and "5" was reduced in favor of that of the subregions associated with fingers "2" and "3" (that of the subregion associated with finger "4" had not changed).

This means that more neurons responded to fingers "2" and "3" after this period of exercises, which allowed the animal to have increased sensitivity in these fingers.

This example shows, if any proof were still needed, that our nervous system is able to adapt to the tasks it is charged with performing, especially if they are repetitive. The example of the monkey also applies to a surgeon, a musician, an artisan or even a computer specialist, who, with time and experience, develops new approaches based on the circumstances with which they are faced.

Neuroplasticity is a phenomenon that changes with time. At birth, it is closely linked to the environment in which the child grows up. All its activities, interactions with the environment and experiences will contribute to the structure of its brain. When they reach adulthood, they will not be obliged to make use of all the notions that were instilled in them from birth.

All this information will contribute unknowingly to the organization of the synapses and the brain as a whole. Note that during this time, the individual's brain is particularly sensitive to any negative elements, such as stress, anxiety and psychoactive substances.

What about neurons? Do we lose or gain them as we age? In fact, both are correct. Santiago Ramón y Cajal, who is rightfully considered the father of neurobiology, believed that the number of neurons

remained stable at best. In principle, it decreased with time, which explained the difficulties we encounter with learning as we age.

In the 1960s, Joseph Altman came to a different conclusion. Experiments performed on mice showed that new neurons were constantly appearing throughout their life. In 1998, the phenomenon was finally observed for the first time in humans.

Thus, the nervous system continues to produce neurons. This activity takes place primarily in:

- the hippocampus, which plays an important role in the proper functioning of the memory;
- the olfactory neuroepithelium, which plays a major role in managing the olfactory functions;
- the cerebral cortex, which is involved in the management of language, conscious perception, decision making, voluntary movements and abstraction.

In parallel, we also lose a considerable percentage of neurons each day and, unlike the epithelial cells for example, they are not replaced automatically. Ageing, lifestyle, living conditions and some conditions (neurodegenerative disorders) have a significant impact on the percentage of neurons lost.

If we understand the mechanisms of neuroplasticity, we can gain a more precise idea of the processes involved in memorization and learning. This helps us to use them in an optimal manner so we can hone learning techniques in particular, and the different approaches to education in general.

✪ Neuroscience as a response to educational problems?

When we read magazines and journals, we sometimes get the impression that neuroscience offers a specific response to all educational difficulties. This is not the case, however. It is crucial to avoid giving neuroscience the same central position as electricity was given in the 18th and 19th centuries. It can facilitate teachers' work, but it is not all-powerful.

The brain, in spite all of its achievements, has limits. Moreover, by dint of relying on science to find 'faults' to correct by any means, we end up making healthy people ill. Indeed, in addition to the functioning of the brain and nervous system themselves, many other factors are involved in the processes of memory and learning.

We can take the relationship between a teacher and student as an example. An attentive, patient teacher can overcome any difficulties their students have with learning. Meanwhile, even the best scientist, who does not possess this talent but who has mastered neuroscience perfectly, could cause even the best student to fail.

Techniques to boost learning

Learning methods remained unchanged for centuries, in large part due to gaps in science. The function of the nervous system in general and the brain in particular remained unknown. This is no longer the case today, and it would be a waste if we did not put all the knowledge we now possess into practice. The following techniques will help both teachers and students alike:

- **Captivate students and always maintain their attention.** Memorization can only happen if there is an optimal level of interest in the lesson. The less interested the student is in what is being taught, the less likely they will be to remember it.
- **Encourage active participation.** The secret to effective repetitive lessons lies in the obligation for the student to take a very active role in the learning process. When they are not involved in the process, its impact is reduced considerably.
- **No mistake is fatal.** The biggest error that many teachers make is to stigmatize the student when they make a mistake. It has been scientifically proven that stress and anxiety have negative consequences on the memory capacity. As such, rather than criticizing the student harshly, it is better to encourage them to keep trying.
- **Learning must have a purpose.** One of the questions most frequently asked by students who struggle with maths is "When am I going to use this in life?" It is easy to arouse the student's interest in any subject once they perceive the practical side of what they are learning.
- **All the sensory organs are involved in learning.** The more the sensory organs are engaged during learning, the quicker the material will be retained.
- **All successful students need to get enough sleep.** Nervous fatigue reduces the memory capacity and learning ability with it.

Although they might seem banal and insignificant, these techniques remain highly effective.

Conclusion

Over the course of their life, humans never stop learning. From birth, it helps them to acquire the skills they need to develop. They learn to sit up by themselves, then to crawl, and then to walk. With the help of their parents or those who raise them, they then learn to use the toilet, language, societal rules, what is good and what is bad, what can hurt them and what is good for them.

Naturally, this learning continues at school. The student learns different subjects in order to acquire all kinds of knowledge that will help them to choose a job for their future life. At this stage, learning is often synonymous with stress and pressure. It is therefore up to the teacher to adapt or rethink their learning methods in order to make knowledge more attractive and learning a painless experience.

However, learning can also be a pleasure, and this is often the case when we practice a hobby, sport or other discipline that we enjoy. Isn't everything much easier when we do it wholeheartedly and with a genuine desire?