

MODULE 3. Feedback and Motor Adjustment

Unit 3.1 Neurocybernetics

3.1.3 Introductory Remarks

Towards the end of the 1980s and the beginning of the 1990s, two dominant paradigms coexisted in the western world. In the 1960s and 1970s, exercise physiology practically revolved around maximum oxygen consumption. In contrast, in the 1980s and 1990s, lactate was the central focus of exercise physiology. We were looking at a subcellular focus on human movement, where even the doctors that taught us physiology were telling us: "you don't train people, you train enzymes and mitochondria". So when it came time to make decisions in the context of training practices, we limited ourselves to physiological aspects that were practically subcellular (enzymes and mitochondria).

On the other hand, based on the theory of motor control, there was growing interest in execution mechanisms, that is, in efference. We had a lot of information on how the order came from the primary motor cortex until it reached the muscle, but with very little knowledge on afferent sensory mechanisms, that is, everything that happened along the "outgoing journey" from the receptors. Information related to afferent organization of movement was scarce.

Personally, during the 1990s, we worked with gymnasts, in rhythmic gymnastics in particular. Whenever we found ourselves working with students that were genetically blessed for flexibility training, we didn't have any problems. But, what happened with those who were less genetically blessed? In the study of the nervous system, and in stimulation patterns of proprioceptors in particular, we discovered the possibility of triggering inhibitory reflexes that allowed girls who had flexibility problems to relax and achieve great results by neutralizing the contractile reflex response to stretching (myotatic traction reflex).

At that time, we also performed experiments with all of the ideomotor representation work, even though we did not yet know about the neural correlates of the act of imagining. We worked on ideomotor representation, that is, the capacity to imagine what is going to happen. Through this work, we saw an improvement in motor performance among gymnasts, soccer players and rugby players, even an improvement in anticipation mechanisms. While they trained, with confidence in these methods, we could see an improvement in regulating the motor act just by imagining the movement, something that is known today as **imagery or ideomotor representation**. For this reason, in the 1990s we began to suspect that the mental action of ideomotor representation generated peripheral neural consequences that facilitated the action of muscle



contraction. Today, based on advances in neurophysiology, the study of this field has expanded.

In flexibility, the majority of neurophysiology studies were published in the book *Amplitud de Movimiento* [Range of Movement] (Di Santo, 2013), with a large number of combinations of proprioceptive stimulation, the objective of which was to trigger inhibitory reflexes.

We had our first experience with this through a course at Universidad Provincial de Córdoba between 1998 and 2002. In these first 4 or 5 years of experience studying the neural correlates of motor act, we discovered methodologies for its application. This course was called Applied Psychomotricity and was developed with the following criteria: we choose to take the different steps of sequential information processing that sustain voluntary human movement and aimed to expound on the anatomy-physiology specific to each one of the sequential steps (acknowledging that there are also parallel processes). Then, based on the study of these steps, we wanted to uncover a special teaching method. As we internalized the information more and more, for example, on the structure of the retina, the more enriching the special visual training methodology became. Another example is that from the study of the superstructure of the optic chiasm we could deduce, as an alternative, how to design special glasses to block nasal and temporal halves of the retinas in the hemibodies in order to increase the use of visual information processing by one of the two occipital lobes. Based on the study of crystalline, we could design exercises to focus central objects in relation to peripheral objects and do the same with other functions or other serial processes where expanding on biological understanding could strengthen teaching methods.

In this course, we will begin to see what the serial processes are and what identifiable and distinct functions among them substantiate a special teaching method to train them.

3.1.2 Cybernetic Model

The neurocybernetic model of information processing demonstrates that we recognize at least 3 broad instances, which are, precisely:

- 1) **Afferent organization or input**, that is, everything that happens to data collected from external sources, as well as from internal sources, until it is processed in very specific locations of the cerebral cortex.
- 2) The second instance is **central processing**, which deals, fundamentally, with the inherent functions of motor logic, decision-making and neuromotor programming.
- 3) The last instance is called **efferent organization or output**.

If we go into more exhaustive detail, we can actually recognize 6 major phenomena, which we call serial in the sense that one triggers the next and the quality of the first conditions the quality of the second. These serial steps that we will analyze and study in detail in order to come up with a teaching method are:



- Sensation.
- Perception.
- Representation.
- Motor logic and decision-making.
- Neuromotor programming.
- Motor execution and control.

Parallel phenomena like feedback are processes that allow these serial phenomena to be adjusted and calibrated. There are also other parallel phenomena like, for example, memory (always present), emotional phenomena, the debate regarding motivation as a serial or parallel process (if it is present at all times during execution of a voluntary motor act or if it eventually becomes part of one very specific point in the sequential process), the phenomenon of attention and different neural correlates of the motor act that help us to articulate a special teaching method.

Information Processing

The information processing theory emerged in response to behaviorism and Gestalt psychology. Its principle concern is in regard to the so-called "**channeling capacity**", which is: how much information the nervous system can properly process when we execute an intelligent voluntary movement. With regard to this analysis, learning how we process information may change the way we choose to teach. This is especially significant when reflecting on the quantity of information a subject can be given in the different stages of motor learning and in skills training, as well as the quantity of information that can be produced in order to acquire, perfect or stabilize. Along with cybernetics, the theory has had a large impact on the theory and practice of correcting failures.

Essentially, the term cybernetic model refers to the information processing system carried out by an athlete when executing a motor praxis. In short, we are questioning what happens in a subject's brain and in the rest of their nervous system when they complete a movement. The term also implies a clear detection of differential stages that are often studied separately, bringing about interesting changes in the teaching methods in athletes and specific functional units. The study of neural correlates has to do with the trainability of the motor functions.

Cybernetics stems from **information processing theories**. It is a branch of information processing concerned with feedback mechanisms as the main focus of analysis. In this context, it studies in detail the way in which returning information is processed in order to regulate movement and for the continuity of the motor learning process. Its objective is to make the subject able to properly address and capitalize on feedback, with the goal of progressively eliminating the need for outside monitoring. To do so, it is key to capitalize on the feedback that contributes to a higher quality of motor programming in subsequent executions. Directing the executor's attention is one of the most important goals of pedagogical interventions. Selectiveness directed by attention allows us to discard irrelevant information and effectively use necessary information in order to improve performance in subsequent executions. The executor should know which



information he should direct his attention towards and, by being aware of the constituent traits of a well-executed movement, compare his execution and correct motor programs.

A few decades ago, all of our training was directed at compressing human movement from a subcellular context, with the objective of leaving out central processes that, in the end, direct all other reactions. Today we understand that a new paradigm is growing, which is alternative to but not more important than the subcellular focus of human movement, which is intimately related to the study of neuroscience.

3.1.3 Serial and Parallel Processes

Within what we call the cybernetic model, we can distinguish between **sequential or serial processes** and **simultaneous or parallel processes**, which influence, in one way or another, motor act.

Sequential or Serial Processes

There are 8 major sequential phenomena. These happen in a specific order, and each one triggers the next: the quality of the first conditions the quality of the second, and so on.

Let's think about the following: "the quality of the construction of the entire objective based on perception depends on the quality of the sensation". In turn, sensation is trainable, so we can work on training the discriminatory capacity of our receptors by stimulating the sensory functions in order to obtain a higher subsequent perceptual quality.

That said, we can deduce that we will never be able to perceive better than we can sense, as each process depends on the quality of the previous one.

- 1) **Sensation:** Sensation is everything that happens as of the change or alteration in the resting potential of a receptor up until all of that data, all of that information, reaches the primary cortex. In these primary projection areas, there is an increase in the thickness of granular layers for information reception (areas 17, 3, 1, 2, 41). Sensation does not provide us with unified data on the object. Sensation is the first step that allows us to gather information to then construct integrated objects.
- 2) **Perception:** Perception provides a great quantity of conflicting theories. Let's remember that the task of perception is the unification of an object in our consciousness, in which the influence of past experience, relationships with similar information on other objects and associated emotions all come into play. Neural correlates have been identified for the phenomenon of perception. For example, in area 17, neurons have been identified for nearly all of the individual features of an object: neurons that are activated according to the spectrum of



visible waves, as well as neurons for lines at different angles (later, through a creative process, we complete what is missing in order to finishing perceiving an object). In the temporal area for hearing (areas 40, 41), as well as in the visual areas, individual neurons that react to specific features of the object have been identified.

However, perception remains a mystery as far as how our brains combine this information, integrate it, and construct a unified object in our consciousness. We know that perception is more trainable than sensation and that the act of perceiving is in itself an act of muscle activation. When mirror neurons were discovered, a lot of attention was drawn to how a primate's primary motor cortex activated the columns that then, by way of the corticospinal tract, innervated the specific muscles that were acting in the moving object. The primate activated muscles by seeing a movement, but without moving.

Thus, when we see a movement, even if we do not move, we activate the same muscles as the subject who is moving. What is interesting about this is that the quality of what we see depends on the quality of what we immediately activate. The act of perceiving is a neuromotor activation and this justifies what is referred to as **training by representation**. When we improve the quality of observation, we learn to discard what is irrelevant and thus we are able to direct our visual attention to some very specific features of human movement. This facilitates pre-activation of neural pathways that then coordinate the movement.

The act of perceiving is an act of facilitating neural paths that regulate motor act; therefore, we can also **train by means of observation**, complementing other solutions to refine the quality of the movement technique. This is a very important tool to be used in conjunction with representation and verbalization of observation. At the time, a few interesting guidelines arose as to how we can train motor observation in order to take advantage of these neural subsystems that facilitate the nervous system. And when we talk about facilitating the nervous system, we are talking about making the post-synaptic membrane of the neurons that make up these pathways more sensitive, in order to thus generate greater activation accessibility of these same pathways through this pre-facilitation.

- 3) Representation:** The quality of subsequent ideomotor representation depends on the quality of perception. Ask yourself: Do we always represent ourselves post-perceptually even when there is no act of volition that implies generating, maintaining and transforming an image in our consciousness? One may voluntarily make an effort to build an image of movement and try to maintain it with as little variation as possible, or otherwise transform the image in the sense of executing the movement better in our minds than we actually execute it in reality in order to thereby generate very specific motor consequences.

The question is: Do we always neurologically post-discharge after having perceived? Do the same neurons that are responsible for the perceptual system discharge post-perceptually and generate images? Apparently, yes. Perception is always followed by a subsequent image.

Ideomotor training takes this phenomenon and trains it voluntarily. Ideomotor representation is an act that has tremendous neural consequences that can facilitate movement or can even worsen it when there is a lack of confidence in



using this tool, or when we are unable to represent the movement in our mind correctly, that is, without fluidity or with interruptions.

Vision is important in order to construct the image, but an image is also much more complete when the person can create information in our consciousness that is not just visual, but also kinesthetic. Let's remember that when we represent what our perception showed us initially, and it does so through an act of volition that generates and sustains a the image of a movement in our consciousness, not only are we facilitating neural pathways that later adjust, control and regulate the movement, but we are also generating muscular micro-activity with stimulation of proprioceptors. Today we know that even the intrafusal fibers and the Golgi organ are activated when we accurately imagine a movement, even though we are not actually executing it.

There are very specific areas of the cerebral cortex that are activated between the area of neuromotor programming and the execution or primary motor areas when we imagine movement as a very fluid activity. There are also differences in terms of using neurophysiological substrates to imagine depending on whether we are inexperienced or beginners or have solid experience. For example, the use of the cerebellum in regulating movement is much more fluid for experienced athletes than it is for inexperienced ones. The cerebellum can block parasitic activations during the act of imagining. The request from parietal sectors for multiple planes of an image of movement is greater in experts than it is in inexperienced athletes. We can deduce major teaching consequences from studying the act of imagining, which can be an enabling tool, or not, if we do not know how to use it properly or when there is skepticism, lack of confidence or we are in a bad mood when using it.

If we take the area of articulated language, the lower third of the ascendant frontal convolution (Broca area) and recognize the tremendous relation between the capacity to verbalize critical aspects of movement and the quality of their programming and execution, that is, when we know that by verbally describing certain biomechanical, energetic, perceptual and motivational features of movement, observing the movement because we have been taught to detect critical points and discard what is irrelevant, as well as imagining the movement because we have been trained to do so, the integration of these three tools (observing, imagining and verbalizing) allows athletes to improve the quality of ideomotor representation, the quality of regulation of the motor act and, in turn, this allows them to know when to stop using it so as not to interfere with the act of programming and generate what is called **paralysis by analysis**. These important phenomena are part of what is called afferent organization of human movement: sensation, perception and representation, with verbalization as an ally.

- 4) Motor logic and decision-making:** These correlates are part of the decision-making process. It is not uncommon to find overly cautious athletes who assemble excellent motor programs, but who are slow in deciding to implement them, or who have regrets in the middle of executing a movement. What is it that fails and what is it that works well in others that leads them to not decide to execute, delay initiating actions or block their implementation? This is the point where we expand our study of area 6, which is responsible for planning and programming movement, and for the supplementary motor area, in order to understand why we



ultimately decide to execute or not. Neuromotor programming has some related debates: Are motor programs located in the cerebral cortex? Do they have a specific anatomical record that we could observe? Or are there no actual motor programs and only construction processes? We lean towards the second position, and understand that beyond just talking about motor programs as underlying anatomical structures, neuromotor programming is an action, a process, that consists of setting invariant parameters.

What part of human movement is recorded in our memory? Where is human movement housed? Does something like a motor archive exist, with a specific anatomical location? It is unlikely. Human movements are distributed into circuits, connection systems, short loops and long loops. Some call these loops engrams, as they are part of a circuit with a very specific spatial arrangement in relation to different neurons. We have engrams in the parietal, temporal and occipital sectors, although there is not a complete consensus on this fact. Despite this, we understand that there is some kind of motor memory and that it is stored long-term with a specific anatomical configuration.

In this **motor memory**, the engram has very specific components that determine the spatial and temporal organization of the movement, but let's remember that the protagonists of the action, which include muscle group, muscle, fiber, and even the total time of the action, are not part of the engram (nor, therefore, motor memory). The engram only houses the spatial data on the movement, which has to do with the articulating nuclei and temporal data point or structure that is the temporal sequencing or proportionality.

- 5) **Neuromotor programming:** What is programming? It is the act of decision-making regulated or commanded by the frontal cortex, in particular by area 6 or the psycho-motor sector which plays the leading role in the action. Programming is, precisely, *setting parameters for an engram*, that is, deciding what muscles will deploy, what fascicles, what motor units, and what the total velocity of the execution of the movement will be. Programming a movement is setting invariant parameters, it is selecting the appropriate kinesthetic melody for each action, always in relation to the prior processes.
- 6) **Execution and motor control:** This point focuses on putting all of the processes previously described into action. Here the main actor is the skeletal striated muscle, always with the co-participation of the CNS, which is responsible for making adjustments to the motor program, or directly switching to another if the situation requires it.
The information that the CNS could receive from the exteroceptors and interoceptors is extremely important to determining if any modification to the motor program in process is necessary.
- 7) **Final or resolving value:** Here we can distinguish the actions of the cerebellum, understanding that this will compare the motor program that we are carrying out with the intended motor program.



Parallel phenomena cannot be pinned down to a specific moment, but rather they condition the activity throughout its entire development. Among these, we can mention the following:

- Feedback.
- Attention.
- Motor memory.
- Motivation.
- Emotional states and processes.

Emotions affect not only the regulation of muscle tone, but also the regulation of the motor act itself. But we try not to study *emotions emotionally*; we try to avoid receiving romantic ideas and study them as neurophysiological phenomena developed through evolutionary history as an advantage for survival. Each emotion depends on a different neural correlate. Different neural populations process different emotional states, many of them in the limbic lobe, but many neural coalitions are generated from the participation of neural subpopulations in the frontal, parietal, temporal and occipital lobes. A common feature of all emotional states is that all the axons that process emotional states are supported by the basal ganglia. We can disguise emotions through gestures or through what we say, but one thing that we cannot hide from the perspective of emotions is muscle tone. There is no emotional dimension that does not provoke a change in muscle tone, fundamentally in the facial muscles. Emotions influence all of the processes of regulation of human movement with respect to sensation, perception, representation, motor logic, motor programming, execution and monitoring. Therefore, we study how emotions affect and intervene in regulating the motor act, as well as strategies for controlling them. We have now reached a point in evolutionary history where the channels that communicate emotion to reason are more developed than the channels that communicate reason to emotion. This is why it is so easy to alter a rational process with an emotional process and it is so difficult to control an emotional process with a rational action.

We could debate whether motivation is a serial or parallel phenomenon, fundamentally from the neurochemical perspective (dopamine) and how it influences different areas of the cerebral cortex, above all in the supplementary motor area, facilitating the initiation of actions and impeding their blocking. We study motivation more from the biological perspective than from the operative-teaching point of view.

Neurotrophins and movement

Regular training increases the concentration of neurotrophins. These pass through the blood-brain barrier and operate as fertilizers of **neuroplasticity**. Neuroplasticity is not the same as neurogenesis. Plasticity implies a neural branching, a neural reconnection, a production of new synapses where that sector, in disuse due to injury or for whatever reason, is recovered in new synaptic branches, which increases activity. Exercise stimulates the production of chemical factors that regulate neuroplasticity and can even regain use in sectors of the cortex that were not being employed due to disuse or injury. These neurotrophic cerebral factors stimulated by movement were mainly



studied in the hippocampus, the memory hub, an important bilateral structure for producing new memories. Today we know that other sectors of the cerebral cortex benefit from the increase in the concentration of neurotrophins, stimulated by fundamentally aerobic exercise. We also know that when we move we have a higher concentration of neurotrophins, but when we move and at the same solve cognitive problems, that is, we think, the increase in neurotrophin concentration is higher. Today, at a time when degenerative brain diseases cause more problems than cardiometabolic risk factors, it is very important to articulate a physical training teaching method that incorporates cognitive functions in order to, in this way, battle the degenerative brain diseases that are causing so much damage in the global population.

Neuro-training

Training based on neurobiology would imply, among other things, not repeating or copying, but rather working on alternatives and variability, versatile application of different motor programs, promoting decision-making and making the process of selecting a motor program the key to our interventions; in short, training tools like observing, imagining and verbalizing, complementing, at the same time, the motor execution process, always impeding the phenomenon of paralysis by analysis, and always demanding reasoning, that is, cognitively involving ourselves in the motor act itself. We understand that this is what makes this training system different. Thus, the target is not just muscle fiber, enzymes and mitochondria, but rather that the attentional focus shifts to the higher brain functions, perceptual and decision-making ones, that is cognitive functions as the main objects of our interventions. We understand these not with simple activities, but rather with complex activities, understanding that complexity is not the same as risk. Complexity has to do with making selecting programs more difficult, as long as this can be done in safe, low-risk contexts. We encourage the promotion of complexity, understanding that the main risk is not taking the challenge. The organ that suffers from a lack of complexity is the brain, and making things that were once easy more difficult, without increasing risk, is one of the main objectives of these kinds of interventions.

In the XXI century, it is important to study the superior cortical functions in order to develop a teaching method for training that incorporates and develops them not just to improve quality of life, but also to battle those tremendous degenerative brain diseases, and, at the same time, delay their appearance and promote beneficial activities not only in older adults, but in the entire population (Di Santo, 2015).

3.1.4 Thoughts on Teaching

Neurocybernetics of the motor act

- Can we incorporate these concepts into physical education, even in schools? We should work to integrate neurophysiological and biomechanical knowledge.



- Pierre Vayer and Pierre Toulouse: "School ignores the existence of the nervous system". Perhaps physical education does too.
- This is what we are attempting: to base the educational process not only on the structure of the object, but also on that of the subject; that is, not just as a social subject but also as a biological subject! And, above all else, taking into account the current state of the biological disposition of the subject for motor learning.
- We cannot deny biology in human movement (Di Santo, 2015).



Unit 3.2 Feedback

3.2.1 Introductory Concepts

The topic of feedback is one of the most fascinating subjects, with major teaching consequences. Its first use is to facilitate understanding the processes of monitoring and regulating motor act: the way in which reafferent information is used to correct, either the same movement before it finishes, or the next movement. The second use refers to the correction of errors and understanding its special teaching method in order to improve learning and increase motivation. The concept of feedback is closely related to neurocybernetics, which, let's recall, stems from **information processing theory** (channeling capacity) as an alternative to Gestalt and behaviorism, both dominant until the middle of the XX century.

The importance of feedback has to do with the following:

- There is an indispensable condition for learning in and of itself, and with this help, we can evaluate both the process and the result of the movement.
- It does not appear to be a crucial condition for the execution of already learned and automatic movements.
- It is not just important to understand and know how to provide feedback as an instructor, but also, and above all, to teach it to the athlete.
- It is important to teach the athlete to pay attention to it, recognize it and use it appropriately for self-correction.
- For Soviet authors, specialists in the study of movement, the human being needs to understand the effect and usefulness of his actions, that is, recognize results. Recognizing results is fundamental for motor learning and technique training.

Ruíz Pérez (1994) summarized the function of understanding results in order to strengthen the following:

- Inform.
- Provide incentives.
- Reinforce.

The concept of an examined life is ancient. Many philosophers promoted it as fundamental in athletic life just as in any of life's other aspects. Understanding the results of one's own actions is incredibly important. Socrates said: "An unexamined life is not worth living".

We will begin with three major classifications, presented by three excellent authors:

- Jacques Corraze (1988): author of *Las Bases Neuropsicológicas del Movimiento Humano [Neuropsychological Foundations of Movement]* raises an ideal analysis.
- Rigal (1987): the concepts drawn from his books *Motricidad Humana [Human Motor Function]* and *Motricidad: aproximación neurofisiológica [Motor Function: neurophysiological approximation]* are crucial.



- Grosser (1988): he considers the topic in detail in his two books related to training athletic technique.

The first classification belongs to Jacques Coraze (1988), in his book *Las bases neuropsicologías del movimiento [Neuropsychological Foundations of Movement]*, dividing feedback and its practice in two:

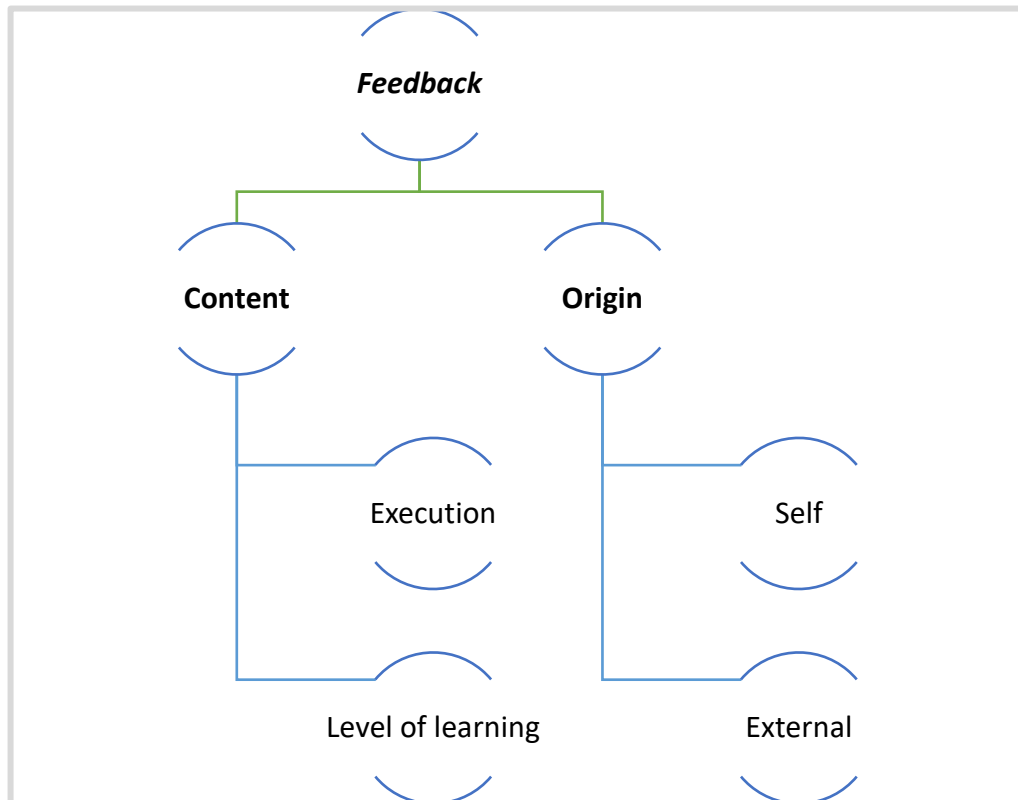
- Terminal Feedback: is that which is based on the reafferences that end the movement.
- Simultaneous feedback: is directed towards the reafferences that are present throughout the entire movement.
- The second classification is by Robert Rigal (1987), which stems from comparisons of human movements:
- Control in closed loop: is based in the use of feedback or reafferences. The movement is corrected as it is developed (for example: the system of controlling the temperature of a house by means of a thermostat).
- Control in open loop: this is based on programming prior to the action, where the necessary instructions are programmed before triggering said action, which is executed independently from simultaneous effects (example: an automatic washing machine).

The third classification comes from Grosser and Neumaier (1988). This classification by Manfred Grosser and August Neumaier (*technik training*) allows an initial approach to the possibilities of feedback in the universe of motor learning and technique training (Grosser, 1988).

We can see this in figure 1.



Figure 1: *Feedback*



Source: Prepared by the author.

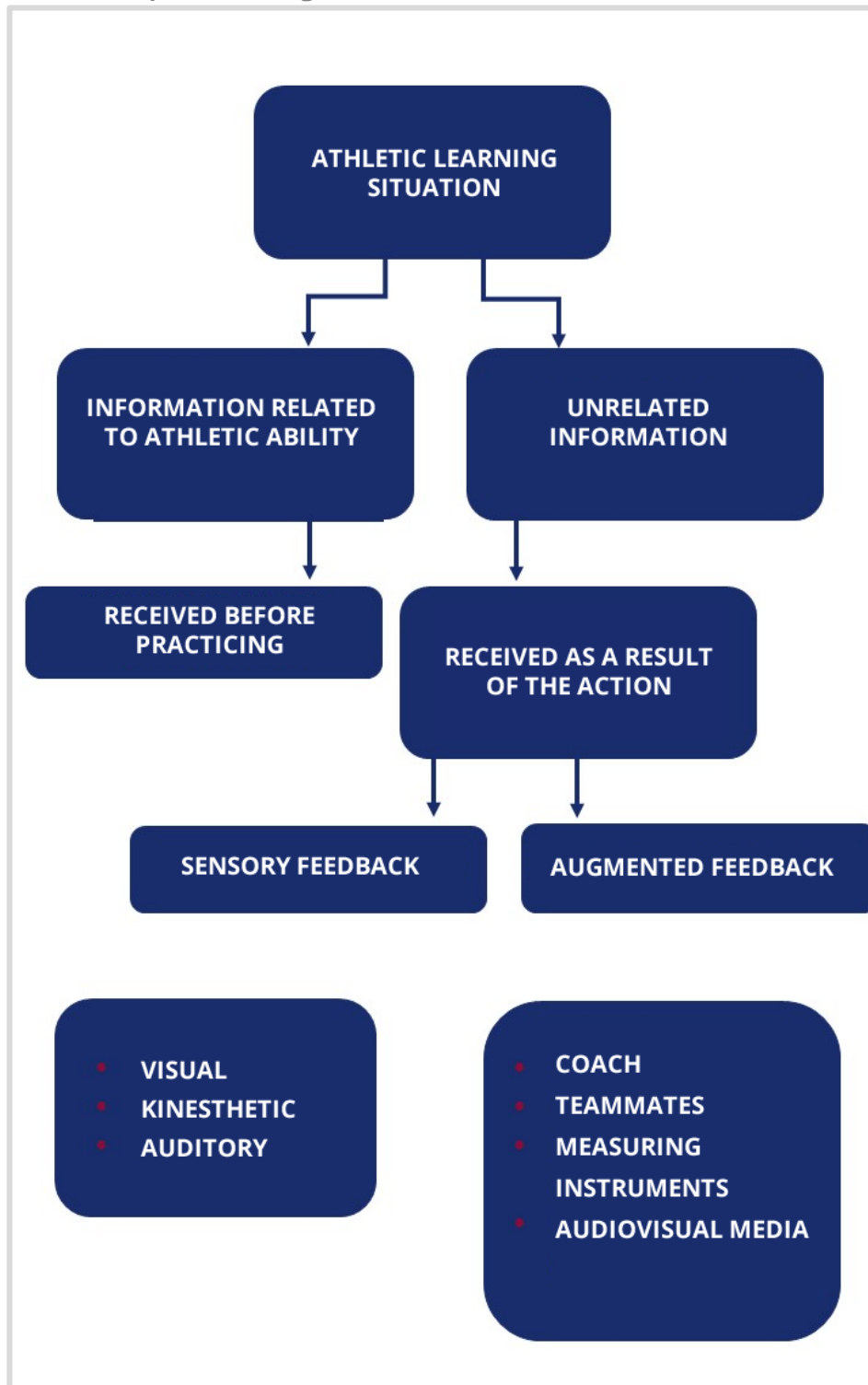
3.2.2 Neurocybernetics and Feedback

In the learning process, the athlete needs to understand the results. Among the tasks that the coach or teacher should carry out, we highlight the information that he should provide to the student regarding what he is achieving and how he is doing it.

In the learning process, the athlete, by experiencing different practices, obtains diverse sensory information regarding his own performance, which will be stored in his memory and can be used to progress in his learning (Pérez, 1994).



Figure 2: Situation of sports learning



Source: Adapted from Schmidt, 1982, cited in Pérez, 1994, p. 226.

According to Pérez, (1994), who based his work on diverse studies, it is necessary to take into account various aspects when transmitting an understanding of results to our students. Below, we mention the following:



Precision of information regarding results

In the entire learning process, providing information regarding results is essential for correcting errors.

In the initial phase, providing too detailed information regarding motor executions can make the process more clumsy; thus, the information should be more general and not so analytical. To provide knowledge regarding results, we have to take into account the person who is learning and his capacity for analyzing and processing information.

As the student gains experience, the amount of information that he can process will also increase.

Amount of information and knowledge regarding results

Often, those responsible for providing information are tempted to give extensive discourses to their students. These long talks during practice can be counterproductive for student attention levels and memory because they are trying to retain so much information.

A few corrections regarding relevant aspects are what will actually have a significant influence on learning. We need to avoid giving information on every aspect of the implementation of a determined ability or physical situation; on the contrary, we have to pay attention to what is really important. In the same way, giving scant feedback on the results also impedes learning.

Ideal moment to provide information regarding results

"Pôlhman (1979) has shown that feedback given within a span of less than 5 minutes can have negative effects. Its instantaneous nature does not allow the student to even minimally assess his own action (sensory feedback)" (Pérez, 1994, p. 230). However, we cannot allow too much time to go by before providing this information, in order to ensure that the student still has the traces of the motor program fresh in his mind.

Frequency of information regarding results

Is it necessary to give feedback regarding results at every moment of practice? This depends on the subject's understanding of the demands of the motor task (Pérez, 1994). Providing information regarding results during all of the practical activities could overload the student's information channels and impede his ability to use this information to improve his motor skills (Pérez, 1994).

Function of information regarding results

Understanding results gives the student information on the activities that he is doing and how he is doing them. Descriptions, assessments or prescriptions are constantly communicated to individuals in athletic teaching sessions. The objective of this is that the student be able to understand the effects of his actions and, thus, be able to know what to do in subsequent sessions. Understanding results motivates the student by



providing him with sufficient encouragement to keep practicing until he achieves the objective. This reinforces the subject's response (Pérez, 1994).

3.2.3 Types of Feedback

Another concept that Corraze (1998) talks to us about is related to **ballistic movement**. A ballistic movement is one in which, due to its speed, cannot be corrected by feedback until it has finished. This does not mean that there is no feedback, as there can be no movement without it. The question is whether the feedback corrects the movement before it ends or not. We consider that, sometimes, a centrally programmed movement should be independent from afferences when it is being developed, but the central program itself contains emergency plans for a variety of different afferences. The question is: how long can a motor program control a movement without taking afferences into account? Ballistic movements, evidently, do not have to be extremely quick.

Some movements that are free from any retroactive control are not the only ones programmed and are not necessarily fast (like the trajectory of a projectile, which cannot be modified retroactively after it has been launched). Some authors even object that no matter how quick a movement is, it can still be corrected.

- Corraze (1988) presents us with the idea of supplementary or artificial feedback:
 - **Supplementary:** adding supplementary reafferences to the task can have a negative effect, that is, subtractive and not additive. Thus, it leads to a deterioration of performance. These effects are clearly explained in specific cases. Providing additional information, whether or not it is redundant, can create an information overload that exceeds the processing capacity of the nervous system. In other cases, the presence of visual reafferences has a negative effect on the others due to what is called capture or predominance (Corraze, 1988).
 - **Artificial:** a context where artificial feedback can be verified is when reafferences are outside of the field of vision. For many motor learning processes, a large part of the activity escapes our sight. Experiments in this field use recordings. Logically, they should present, in the first place, a visual model of the movement to be learned, executed by a well-trained subject, and, during the course of the learning process, show the subjects a film of their own movements (Corraze, 1988).

The **bio-feedback technique** consists of making it possible to monitor a physiological variable by providing information regarding its effects. Given that under ordinary conditions the central nervous system does not perceive these effects, they have to be provided through artificial means. For example, giving the subjects visual or audible



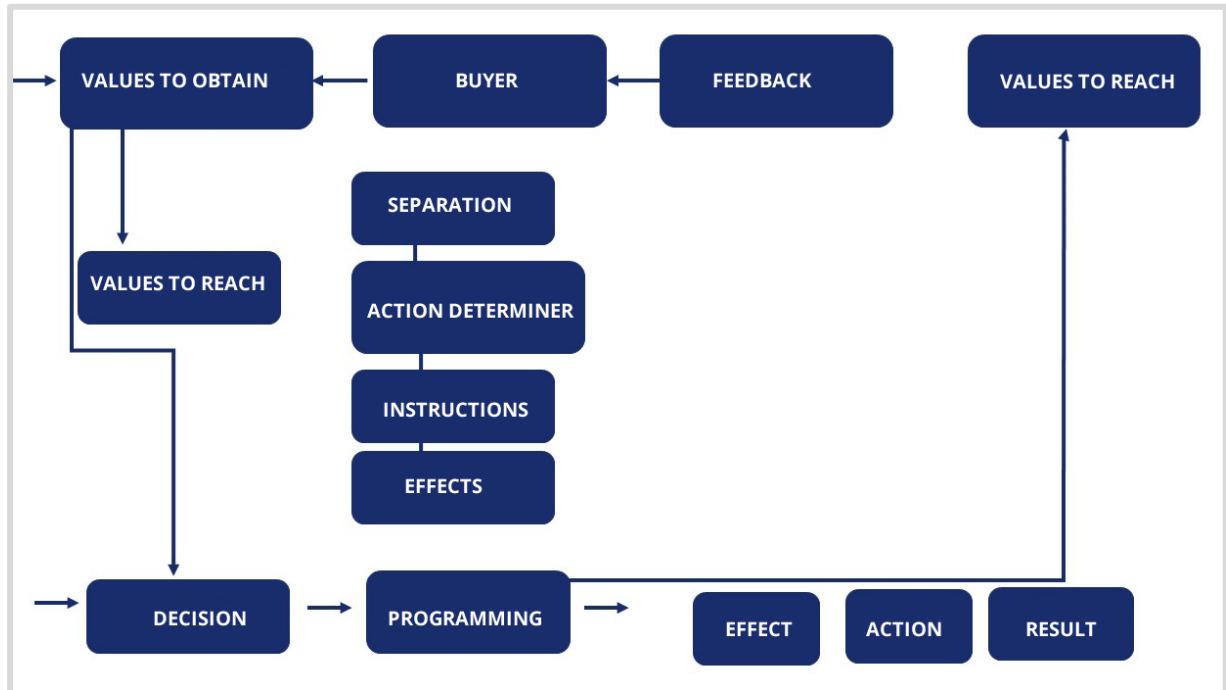
information when they execute a movement is providing them with artificial feedback. This last type of effect has been used to reduce neuromuscular handicaps (Coraze 1988).

A great number of the functions of our body are inaccessible to our consciousness: blood pressure, blood sugar levels, cholesterol, infections or cognitive processes themselves. Bio-feedback gives us access to much of the information that our consciousness cannot access in any other way: its objective is preventive. We ask ourselves: Why is so little accessible to our consciousness? Could this be an advantage? What do we have the best chances of gaining access without the help of auxiliary equipment.

- Rigal's classification (1987): the majority of movement executed with a precise objective in mind is subject to control in one form or another. Generally, the effect of a movement can be used to prepare or modify the next movement, or the required movements could be independent from each other when each one has been programmed in advance and developed without correction (Rigal, 1987).
 - **Closed loop:** The closed loop system is based on the use of feedback or reafferences coming from different pathways such as, for example, proprioceptive, auditory or kinesthetic sensations that provide feedback, on the basis of which a movement can be corrected while it develops. This corresponds to the detection of a difference or an error, and the feedback that instructs the control system in regard to the similarity or difference between the intention and the action. Thus, while executing a movement, the proprioceptive, visual, auditory or kinesthetic intentions provide feedback or reafference regarding its development, on the basis of which it is possible to correct or modify the movement (Rigal, 1987, p. 307). In general, feedback tends to be negative, as it is characterized by trying to bring the value achieved closer to the desired value in an attempt to provide the system with stability. Positive feedback, in contrast, increases separation and destabilizes the system (Rigal 1983, p. 307). Taking Rigal's example (1987) to explain this phenomenon, we refer to the panicked behavior of a crowd, where, the more people start to panic, the more they also lose control, which aggravates the situation (Rigal, 1987). The closed loop model predominates in slow or progressive actions, where there is sufficient time to receive reafferences and carry out adjustments as necessary.
 - **Open loop:** the control system for an open loop is based on programming prior to the action. The necessary instructions are programmed prior to triggering the action that is executed independently of the simultaneous effects. It is not reafferences or retro-actions anymore, but rather efferences or pre-actions that regulate the development of the movement. When we decide to execute a movement, an efferent copy (or a corollary discharge) of the motor order, this decision reaches an encephalic nervous structure where the correct movement models are stored (Rigal, 1987).



Figure 3: Open loop model



Source: Rigal, 1987, p. 306.

3.2.4 Consequences for Teaching

The proposals based on information processing could be:

- **Direct:** the athlete should learn where to direct his attention, which requires that he be provided with prior information.
- **Limit:** the athlete can only assimilate information in a limited framework, so it is important not to overload him.
- **Distinguish:** in order to accomplish this, the coach should distinguish relevant information from irrelevant information and give concrete instructions.
- **Restrict:** information and instructions from the coach should be restricted to a few important points.

Perspectives and discussions

It is necessary to continue expanding the general teaching method on error correction in order to develop new methodological consequences.

Teach how to self-detect and self-correct through the following:

- Hierarchical control.
- Cybernetics.
- Dynamic systems (Di Santo, 2015)

Feedback for maintaining motivation is based on the following:

- Abilities.
- Pain.
- Activities in everyday life.
- Technique.

In turn, this feedback is related to the sources of feedback:

- **Self:** the sooner we have our own information, the greater chances we have of creating a consistent image of movement and improving our programming and motor control. The possibility of achieving complete self-information is not so simple. There are areas of the body that are inaccessible to our vision and other analytical tools.

Some clarifications regarding self-feedback

Self-information is rarely complete:

- **Visual:** consists of what I can see of my body and is inevitably, with regard to self-information, partial (never complete) and, all the same, very important.
- **Auditory:** consists of what I can hear from my body, and, although often very obliquely, it is very important for injury prevention when lifting weights.
- **Touch:** in relation to proprioceptive information, this makes us aware of haptic sensitivity, which is key in motor control processes.

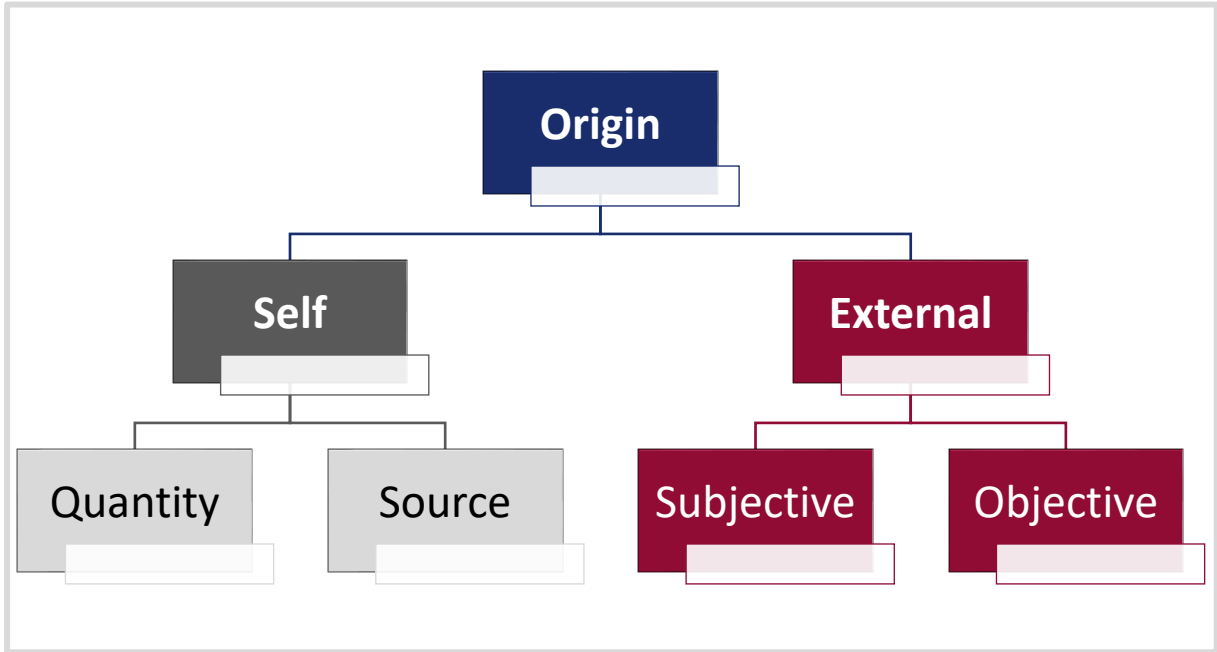
Self-provided information: repeat without repeating

Concentrating on specific sources of information is crucial for one's awareness and production, depending on the athlete's capacity for paying attention and his level of mastery:

- Consciously assimilating information from oneself has a decisive importance in training technique (much more than external information).
- Subjective external feedback is not sufficient, and it is useful to have objective information on one's execution (videos) as soon as possible.
- The athlete needs to learn where to direct his attention to avoid focusing on irrelevant data and to discard information that is not applicable.

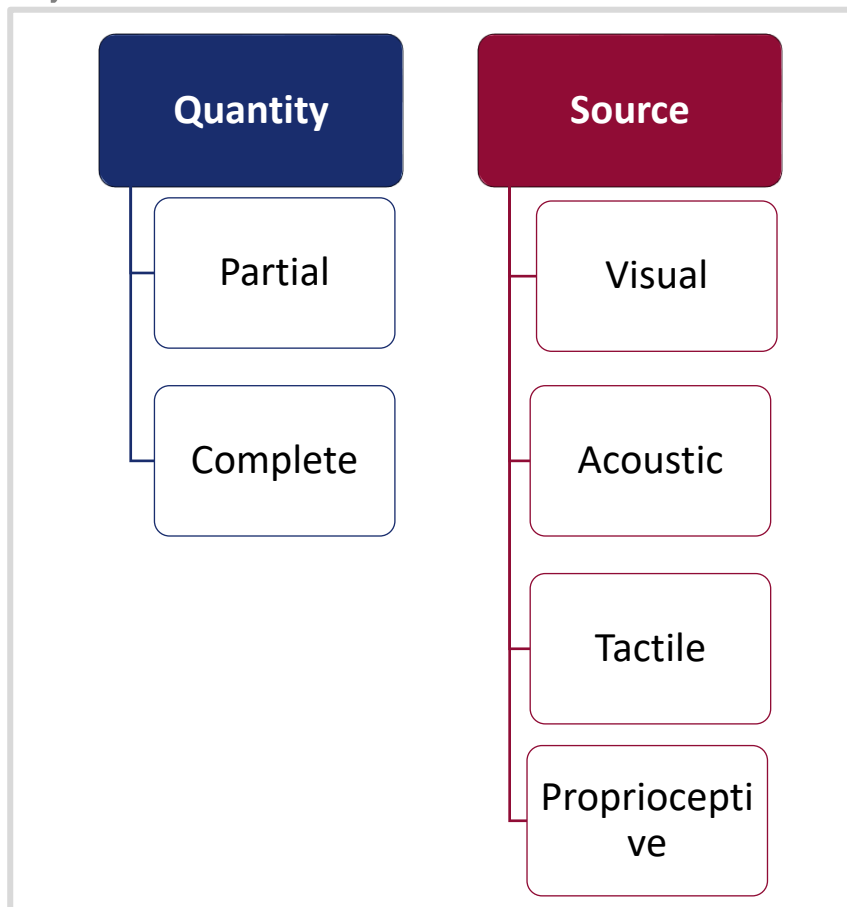


Figure 5: Consequences for teaching



Source: Prepared by the author.

Figure 6: Quantity and source



Source: Prepared by the author.



- External: this is information not generated by the subject himself, but rather provided by outside sources. All information is important (Di Santo, 2015).

In regard to external information:

- Information provided by the athlete himself is often imprecise, incomplete and full of errors.
- The experienced coach often records more data than the athlete himself.
- For this reason, assimilating self-provided information along with external and complementary information, accelerates learning.
- This external information could be both subjective and objective, but it acquires its real value when it is combined with information from the athlete himself.

In regard to subjective external information:

- Subjective information offers an emotional component that objective information does not possess.
- A face or expression can provide more information than words or videos.
- It is key from the motivational perspective.
- It should be taken into account without discarding objective information (combine them).
- No matter how rich the objective information is, without the subjective information, it is difficult.
It would be like learning from manuals.

In regard to verbal comments:

- This is provided by the coach, and comes in different types. Good teachers often combine the different types of verbal comments equally:
 - Perceptual.
 - Biomechanical.
 - Motivational.
 - Energetic.

Consider also:

- Voice quality.
- Voice rhythm.
- Inflexions.
- Resonance.
- Tone of voice (Pérez, 1994).

In regard to non-verbal comments:

- A look often has more power than a word. It is useful to combine both verbal comments and non-verbal comments with objective external information and, in turn, accompany verbal comments with facial and body gestures.



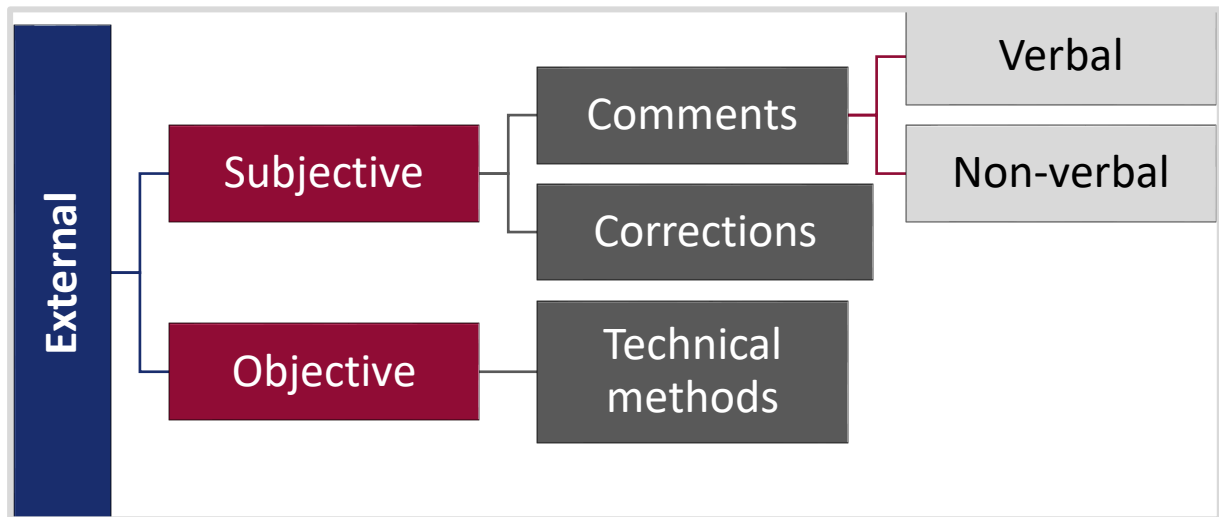
Conditions of the teacher:

- Concentration to observe.
- Determining which subjects will be observed.
- Speed of observation.
- Organization of the session.
- Location of the session.
- Understanding the technique (Pérez, 1994).

In regard to objective external information:

- Photos and stills.
- Videos and special programs.
- Better in the context of training.
- Execute, observe, interact and correct (Pérez, 1994).

Figure 7: External information



Source: Prepared by the author.



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