3.1 Motor imagery

3.1.1 The act of imagining movements and their neural consequences

The quality of perception depends on the quality of the subsequent ideomotor representation. Ask yourself: Do we always represent ourselves post perceptually when there is no act of volition that implies generating, maintaining and transforming an image for our consciousness? One may voluntarily make an effort to build a motor image and try to maintain it with as little variation as possible, or otherwise transform the image in the sense of executing in your mind how best to perform the movement we actually execute in order to generate very specific motor consequences.

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

Ideomotor training takes this phenomenon and trains it on a volitional basis. **Ideomotor representation** is an act that has tremendous neural consequences that can facilitate movement or can make it worse when there is a lack of confidence in using this tool, or when we are unable to represent the movement in our mind correctly, without fluidity or with interruptions.

Vision is important in the construction of the image. Nevertheless, an image is much more complete when a person can generate information not just for our visual awareness, but for our kinesthetic awareness too. We remember that when we represent what our perception showed us initially – and this through an act of volition that generates and sustains a motor image in our consciousness –, not only are we facilitating neural pathways that later adjust, control and regulate the movement, but there is also muscular micro-activity with stimulation of proprioceptors. Today we know that even the intrafusal fibers and the Golgi organ become activated when we accurately imagine a movement even if we are not actually executing it.

There are very specific areas of the cerebral cortex that activate when we imagine movement with a very fluid activity between the area of neuromotor programming and execution or primary motor areas. There are also differences in terms of the use of neurophysiological substrates used to imagine when we are inexperienced or beginners and when we have solid experience. For example: the use of the cerebellum in the regulation of movement is much more fluid in experts than it is in the inexperienced. The cerebellum can block parasitic activations in the act of imagining. The request from parietal sectors for the multiple planes of a motor image is greater in experts than it is in inexperienced athletes. Profound didactic consequences arise from studying the act of imagining and it may be a facilitating tool. However, this is not always the case if we do not know how to use it properly or when there is skepticism, mistrust or a poor attitude towards its use.

If we take the **articulated language area**, the lower third of the ascending frontal gyrus (Broca area) and recognize the tremendous influence the capacity to verbalize critical aspects of movement has over the quality of its programming and execution (when we know to verbally describe certain features, bio-mechanics, energy, perceptions and motivations), we end up with the three necessary tools. When we know how to observe movement because we were taught to detect critical points and discard the irrelevant; when we know how to imagine movement because we have been trained, the integration of these **three tools (observing, imagining and verbalizing)** allows athletes to improve the quality of the ideomotor representation, which improves the quality of regulation of the motor act and, in turn, informs them when to stop using it to prevent interference with the programming act and avoid what is known as **paralysis by analysis**. These important phenomena form part of what is called the afferent organization of human movement: **sensation**, **perception** and **representation** with verbalization as an ally.

3.1.2 Martin's ideomotor response and the carpenter effect

Weineck (2006) defines **ideomotor training** as learning or improving the development of a movement through intense psychic representation, without actual simultaneous exercise; in other words, only through the act of presenting the perceptions of the movement once more to consciousness, ensuring that we include all its components (where kinesthetic data and not just visual information are of particular importance). Its impacts are mainly visible in improved learning and motor control, although it has applications in other dimensions like overall physical fitness and neurological rehabilitation.

The acute responses to the act of mental representation can stem from cortical stimulation in the motor and premotor areas linked to the following effects:

- Muscle micro-spasms.
- Increase in heart rate (HR) and respiration rate.
- Better peripheral vision.

- Greater stimulus of the PNS.
- Facilitation of the neural pathways.

Advantages

Weineck (2006) suggests using these techniques as an excellent tool for overcoming stagnation in training the technique. It allows the athlete to overcome emotional blocks, not as executors, but as professors, in addition to providing precise information to students. Its advantages are that it:

- Improves gestural stability.
- Improves the quality of execution.
- Preserves the technique during interruptions.
- Simulates competitive situations.
- Complements warm-up.
- Reduces anxiety.
- Reduces learning times.

Recommendations

The formation of a detailed motor image constitutes the basis for the development of a higher technical level in the sport and from there, all available resources to form it must be involved. Once the student has learned the task, he or she must make the first practical attempts as improvement can only be achieved based on their own motor experiences and not through instructions. In addition, to configure it correctly, it is important at the beginning of the learning process to provide only the information that is absolutely necessary otherwise there is the danger of excessive interpretive-mental effort. Beginners and advanced athletes alike can work with images of movement, although it is more likely for advanced users to achieve them with higher quality, quite possibly due to the greater availability of kinesthetic sources.

Limitations

This depends on experience. It is not possible to apply it to all sports and it can produce great mental fatigue. It never replaces actual execution and can generate "parasitic" movements if used incorrectly.

Grosser

Two requirements, although insufficient on their own, are needed to perform a motor task. Firstly, athletes must **possess a good image of the course of the movement** asked of them; in other words, the configuration of a more or less precise image and on the other hand, an understanding of the explanations given by the trainer, that is, to **relate the concepts expressed by the trainer with the components of the image.**

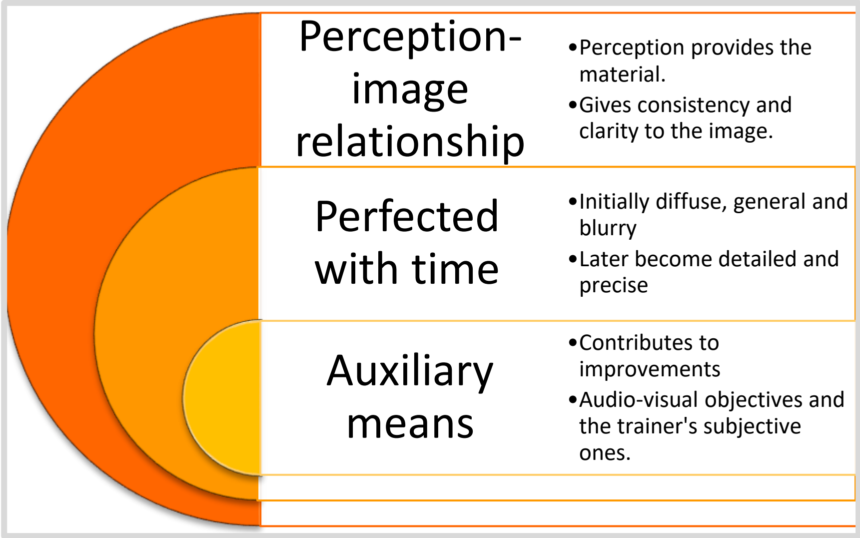
We see that Manfred Grosser (1988) has indicated the basic components that cannot be omitted in performing a motor task properly. The basic components he indicates are:

- **verbal accuracy**: the trainer's linguistic concepts and expressions have to correspond to the athlete's level of motor experience, knowledge and age.
- **clear images**: the athlete or practitioner must have the progressive capability to configure clear and vivid motor images and not just the ability to construct them, but, above all, to control their most relevant constitutive aspects.
- **positive emotions**: these must be present primarily in aspects that are inexorably linked with all motor imagery, which are their emotional components. In summary, motor imagery must include positive emotions.

Grosser (1988) emphasizes that its configuration constitutes a process that takes time, practice and mental preparation. As such, it is a trainable skill whose realization requires a voluntary effort of consciousness. The author alludes to the fact that the composition of the image is formed by internal and external information.

- **External information**: the athlete does not need to move, but instead only needs to request the activity from the exteroceptors, among them, the visual (demonstration, video, photographic) and the verbal-acoustic (descriptions, comments).
- **Internal information**: this type of information is obtained from the athlete's very movements. It requires information primarily from interoceptors, but also information from exteroceptors (visual, acoustic, proprioceptive, tactile, haptic, kinesthetic, statoesthesic) about data from the body itself.

Figure 1: Integration of Motor Imagery



Source: prepared by the author

Grosser (1988) alludes to the term **"mental preoccupation"**. Let's think of the transcendence of this concept: technique as a tool for the development of higher mental functions in humans. In order to create the motor image, it is important for the trainer to constantly present athletes with new tasks that oblige them to focus intensively (mentally) on the technique. Therefore, it is about asking after the important characteristics of the technique, drawing the phases, giving tasks inherent to the perception of the athlete's own movement and that of others. Awareness of the sensations during movement, along with its verbal analysis, constitutes one of the basic conditions for the accuracy of the motor image; what the authors are ultimately trying to tell us is that the quality of the image does not come out of nowhere, but instead depends on factors that can also be trained.

Kinesthetic information is irreplaceable. The best source of complementary information to develop a complete motor image is to actually execute (rehearse) the technique. The different types of verbal descriptions or visualizations of execution by others are necessary conditions, but insufficient on their own. Moreover, these omit the most valuable source of information, kinesthetics. The possibilities of illustrating the movement do not include kinesthetic information which is, however, the most important of them all. External information does not allow the motor image to be completed. A suitable motor image is formed more quickly if attempts to create it are made as soon as possible during learning. The assimilation of external information is much more difficult for beginners as they have no personal references with which to relate what they have observed or what has been corrected by the trainer. This assimilation allows us to compare intrinsic information with extrinsic information; in other words, indicate, demonstrate and correct how relations can be established. It is worth asking the student to perform verbal descriptions of the movement to compare good and bad execution, and compare their own execution against the as yet incomplete and blurry motor image.

Basil Kavanagh cited by (Lacey & Lawson, 2013) is based in Canada. He is a professor at the School of Human Kinetics and Recreation of the Memorial University of Newfoundland, Saint John´s, Canada. He lectures at the school of Sports Psychology and is a trainer of the university's Olympic Curling and Basketball teams. He understands ideomotor representation or motor imagery as “a mental experience that emulates an actual experience”:

- The more polysensorial it is, the more real it becomes.
- It incorporates audio, visual, kinesthetic, tactile and even olfactory senses.
- Its functions are both cognitive and motivational.

Motor imagery impacts directly on both cognitive and motivational functions. **Cognitive** functions have an impact on improving technical gestures, routines, game plans and strategies (to reduce the number of errors and consolidate motor learning processes). **Motivational** aspects act to improve the level of psychological arousal and emotion control (to specify individual goals, manage stress and psychological pressure, achieve mental strength in the face of adversity, self-control, safety and confidence).

When using this tool, Kavanagh (2005) recommends:

- To employ it mostly outside of competition.
- To use it daily (5 minutes, once or twice a day).
- Follow a progressive order (you can become a great imaginer).
- To be in a good mood when practicing it.
- It can be beneficial for all ages.
- Always focus on positive images; never negative ones.

Weinberg (2008) cited by (Lacey & Lawson, 2013) investigates and asks questions about this phenomenon of imagining. He proposes the following questions: What is ideomotor imagery? Does it work in sport? Where, when, why and how? What factors affect its effectiveness? How does it work? What is the main potential for its use? What are the key aspects for ensuring its effectiveness? How can we develop an ideomotor representation training program? When is it best used?

What is ideomotor imagery? The author defines this as “a form of simulation that involves evoking or extracting pieces or traces of information stored in the memory about experiences and giving them shape and precision as significant images for the purpose of creating or recreating an experience in your mind". Achieving this involves all your senses: visual, auditory, tactile, proprioceptive, vestibular, and even olfactory. The kinesthetic sense is particularly important in athletes, as are mood and emotional states.

Does it work? Everything appears to indicate that it does. There are hundreds of anecdotal reports: Tiger Woods, Chris Evert and many more. Psychological interventions show that the imagination combined with other strategies improves performance. Scientific research has revealed many good results: improved learning and actual execution.

In sport, his questions point directly to the use of images as a sporting tool:
When is it used most? Motor imagery techniques can be used before, during, and after practice and competition. It can also be used in injury recovery processes (Di Santo, 2015).

Why are they used? These techniques are used because they may produce improvements in cognitive and motivational functions (Di Santo, 2015).

What is actually imagined? Tasks involve imagining aspects, motor perspectives, and emotional situations (Di Santo, 2015).

The functions that strengthen the use of this technique are:

- **Cognitive functions,** such as skills, techniques, and strategies.
- **Motivational functions**, such as increasing psychological arousal, controlling emotions and setting clear objectives.

What do athletes imagine?

Key aspects to take into account when imagining include:

- Surroundings.
- The negative or positive nature of the image.
- The senses involved.
- The perspectives of the act of imagining, which can be **internal** (camera in the head) or **external** (external observer).

Weinberg proposes that, regardless of the perspective used (internal or external), the most important thing is to find a comfortable style that makes it possible to create clear and controlled images. Without practice, the image is limited and unimodal.

The author develops five theories in order to explain the implementation of this technique:

- **Psychoneuromuscular:** promotes targeted muscle innervation and strengthens neuromuscular pathways.
- **Psychological skill:** the imagination improves concentration and reduces anxiety.
- **Symbolic learning:** functions such as a coding system for clues that help an athlete understand and acquire the movement.
- **Bio-information:** images are made of "stimulus-response" type propositions that make it easier to evoke and control different scenarios.
- **Triple code:** involves the actual image, somatic response, and meaning.

Later we will take a closer look at the most relevant aspects of the Psychoneuromuscular theory.

Weinberg takes a psychological view to also build three explanations that account for the instrumental value of ideomotor representation:

- **Attention-arousal set theory:** the image functions to help achieve optimal arousal (optimal excitability state of the NS).
- **Psychological skills hypothesis:** the image increases confidence, reduces anxiety levels and increases concentration.
- **Motivational function:** increases motivation and the desire to continue training and competing.

Benefits that the author describes in adapting to training:

- Increase in concentration.
- Increase in motivation.
- Builds confidence.
- Control of emotional responses.
- Acquisition, practice and correction of fine motor skills in sports.
- Acquisition and practice strategies.
- Preparation for competition.
- Endure pain and adversity.
- Resolve movement issues.
- Resolve training issues not directly related to motor execution.

Use the tool to:

- Improve execution techniques.
- Control context.
- Imagine your body as you would like it to be.

- Imagine yourself doing things properly and well.
- Imagine yourself being better physically.
- Imagine yourself controlling your emotions.
- Imagine yourself trusting yourself.
- Control the times of the images.

3.1.3 Neural correlates, activation of the premotor cortex and impacts in the cerebellum and basal ganglia

Throughout our lives we have perhaps heard of the ability of great athletes to concentrate and use mental strategies. However, the concepts of concentration and mental power seem to enter into a semantic and practical "grey area" that makes it difficult to accurately identify the brain functions and strategies put into practice when executing motor skills in general. We will try and focus on image creation as a mental strategy for strengthening motor performance.

We start out by supposing that there is something going on beyond the strictly "mental" aspect when we create images of movement:

The positive effect of generating and maintaining images of movement experienced during personal practice as a gymnast gave rise, as a logical consequence, to questions inherent to its possible effects on the neuromuscular system.

The impact of the nervous system on both central (cortical excitation in motor and premotor areas) and peripheral (increase in heart and breathing rate, improvements in peripheral vision, greater excitability of the PNS, neural facilitation, changes in metabolism, muscle micro-activations).

By reading Weineck (2006) we can anticipate that the act of imagining would transcend the exclusive implication of the CNS. This act produces a repetitive modulation of the intra and intercortical, as well as subcortical excitatory processes through **synaptic plasticity**, similar to the phenomena observed after practicing a motor task or gesture.

Activations in the Nervous System from Imagining Movements

The spatial perspective, among other things, allows us to learn a little more about the physiological differences between imagining in first or third person. Moreover, the content of the image determines the specific neural correlates. An image that employs different perspectives places demands on different parts of the cortex; in other words, when we imagine in the first person, we are the protagonists compared to the third person where the protagonist is someone else. First person images, where you are the protagonist, place demands on the right parietal lobe, the inferior sector, the precuneus or posteromedial portion of the parietal lobe and the somatosensory cortex. If on the other hand the image is in the third person or involves imagining a situation with other protagonists, no demands are placed on the same zones. In these the task is more visual, primarily activating Brodman's area 17. It is not the same therefore to imagine in the first and third person as there are differences in the neurological profile and the impact on movement. The neural correlates for the act of imagining in the third person are not exact, therefore the authors agree that it is better to imagine in the first person. Jeannerod (2006) claims that the perspective relates to the self-other distinction: to place the other before the self supposes a division or distinction between self and other (Vogely & Fink 2003).

The reference frameworks can be defined in terms of visual field, head, trunk and longitudinal axis of the segment involved in its action.

Blanke & Arzy (2006) claim that representation in the first person (1PP) activates the inferior portion of the right parietal lobe and the back sector of the temporal lobe. 1PP perspective has more visual, auditory, somatosensory and limbic components than third person representation (3PP) and further involves multi-sensoriality. This is much better for motor control as it corresponds to the phenomenon of cross-modal sensitivity (the sensation of self-possession and self-identification). The image can also be reinforced by synchronizing one's own auditory, visual and kinesthetic memories. This does not happen with 3PP.

Our understanding is that the positive or negative choices have something to do with the conditions of the subject and context analysis. The underlying hypothesis is that both types of representation, first and third person, are teaching resources that apply to different situations. 1PP is ideal for working with the athlete's own movements. But does the creativity of imagining movements for others, as in the case of choreography, come from the self? In this respect we are inclined to think that 3PP could be more useful. Perhaps for the creation of motion aimed at others (more useful for trainers). The bibliography also expresses the importance of the angle. Both (1PP and 3PP) can adopt different angles which may contribute to effectiveness. In summary, it is better to imagine from different angles and not just one (Hardy, 1997).

The primary motor cortex (M1) is also involved in the motor image and this activity improves future motor actions. Holmes (2001) supports the concept of **equivalence in motor functionality.** Areas like the prefrontal

cortex, premotor cortex and the supplementary motor area are involved in the choice and preparation of movement, but not its execution, which is the responsibility of the M1.
Holmes (2001) also alludes to the impact of imagining movements on the cerebellum, which appears to inhibit the motor activity of the M1 (which perhaps makes sense). During motor execution, **cerebellar contribution** involves processing feedback to provide for precision, spatial coordination, and temporal control of movement. Even though cerebellar activity is not necessarily observed in ideomotor representation (as in the M1), when activity does occur, different sensors are activated in the cerebellum from those that are activated during the actual execution of the movement. The upper portions of the posterior lobe of the cerebellum are connected with the premotor and supplementary motor areas, which makes sense. The cortical areas are activated differently depending on the subject's motor and imaginary experience: the greater the experience, the greater the cerebellar activity and the lower the activation of the M1. Apparently, higher activation of the M1 in more inexperienced athletes promotes greater **synkinesis or parasitic activations** of primary movement, which could complicate motor control. During the act of imagining, as experience increases, so too does the number of subsystems that participate in the regulation of fine motor control.

3.1.4 Peripheral activations and impact on proprioceptors

Not everything stays in the CNS. The act of imagining also has repercussions on the alpha and gamma motor neurons, and proprioceptors (primarily the intrafusal fibers and Golgi tendon organ).

These first experiences with the use of these techniques help us to understand that, from a functional viewpoint, they are not purely cortical events. We might believe that the act of imagining refers to a cortical function but it also involves peripheral and specific anatomical functions.

There was a particular experience in the 1990s with a professional soccer player (Luis Fabian Artime), who used these techniques before games, prior to listening to the coaches speak. The assignment consisted of generating images related to technical gestures he might use when marking opponents or scoring. These tasks lasted between 5 and 10 minutes. As the sessions progressed, the athlete would explain how many of the situations that occurred in the games were similar to those he had worked on using this technique. He even stated how he had visualized the majority of the goals he scored in one way or another in the dressing room prior to the match.

The usefulness of this technique has been validated in other sports, such as dance, where the mental aspect is developed as a key component of flexibility training. This technique can have a direct impact on ballerinas from their brain waves to the regulation of muscle tone and reduction of internal resistance to stretching. In conclusion, receiving motor images from the teacher can help improve range of movement, while a bad dose of such images can have negative repercussions.

The director of the image managed a scale that would range from the nonspecific (landscapes, sounds) to firm representations of the body in a state of relaxation. Therefore, we could think specifically about:

- Anatomical structure.
- Functionality.
- The actual gesture.

This tool can be adapted to more than just sport. It is also used in APE (Adapted Physical Education), together with observation and **"self talking",** to generate good results in cases of Parkinson's, equilibrium disorders due to cerebrovascular problems or the re-learning of basic posture and locomotor skills.