THE PERCEPTUAL - MOTOR FUNCTION

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Review paper

Abstract
In the light of the new scientific findings, human movement cannot be understood or studied, without taking into account the perceptual processes and their role over cognitive integration in the action understanding and organization. Starting from the Theory of the Functional System up to the recent concept of the Mirror Neuron System, it has been understood how the Perceptual-Motor Function is intimately linked to cortical areas, classically understood as responsible for other functions. In particular, in the last few years, the role that the Broca's Area plays in the understanding of the action, and therefore in the organization of the Perceptual-Motor Function, is getting increasingly clear. In this perspective, the recent scientific literature focuses on investigating the use of specific verbal instructions as a key element in the learning of motor action.

Key words: *perception, action, functional system, movement, motor performance.*

Introduction

Understanding the organization of human movement, particularly when it concerns the organization of complex motor action, is an important scientific objective. The continuous evolution of neuroscience and modern pedagogical approaches require, even by those involved in Sports and Training Sciences, to examine for new perspectives in the observation of the motor phenomenon, understood as the ability of the human system to express itself through the movement.

From this, we can deduce that human movement cannot be understood, or even studied, without taking into account the perceptual processes, i.e. without considering the integration of the sensory "raw data" into cognitively available information. The motor function and the sensory function, being referable to specific anatomical structures, are often considered separate entities, especially in the sports field. This is an incorrect view that does not reflect the real organizational modalities of the system as a whole, which is instead organized in such a way as to integrate both functions into a higher level. This means that human movement must be seen and studied as a Perceptual-Motor Function, where by function we mean the activity of adapting the whole organism to the environment in which it lives.

It is important to underline that perception and action are essential to each other: perception is not a passive mechanism, but an active one that aims to predict the sensory consequences of an action, thus connecting sensory information and motor commands in a coherent 'computational tissue'. In this context we can define the perceptual-motor acts as entities that allow understanding the complexity of perception, of its organization based on purposes and its link with motor activities; the concept of motor perception is then defined as an analogy with that of motor action in relation to movement. An action can then be defined as a sequence of movements allowing reaching a goal. Perception is not only an interpretation of sensory messages: it is conditioned by action; it is an internal simulation, an evaluation, a choice, and an anticipation of the consequences of an action. Therefore, there cannot be more distinction between perception and action; more specifically, perception is a simulated action (Berthoz, 1998).

From movement to action: the Perceptual-Motor Function

The motor theories of perception that have been developed over the years, consider perception as the process by which sensory stimulation is transformed into organized experience. This experience is the joint product of stimulation and the process itself. Perception is not a passive mechanism through which to receive and interpret sensory data, but it is an active process that anticipates the sensory consequences of an action, and which therefore provides a coherent link between sensory/sensitive and motor patterns. In computational terms, this implies the existence of an "internal model" in the brain that acts as a bridge between action and perception. In fact, the idea that the instructions generated by the brain to control a movement are used by the brain itself to interpret the sensory consequences of a movement, can already be found in the pioneering work of the Russian school, starting from I.P. Pavlov's studies on the nature of reflexes and its subsequent critical review by PëtrKuz'mičAnochin and Nikolai Aleksandrovich Bernstein. In particular, a major contribution to the understanding of the Perceptual-Motor Function comes from the studies carried out by P.K. Anochin, a Soviet neurophysiologist and motor-learning expert, who defined the *Functional System* as a useful model to identify a set of certain physiological manifestations connected to each other in order to fulfill an objective; more precisely, it is a "set of structures and processes variously located, but all aimed at the achievement of a biological target". The *Theory of the Functional System* was described by Anochin (1968) into a *Scheme of the Behavioral Act*, particularly interesting for those who deal with movement and training sciences. In this scheme, in addition to the observable movement, Anochin also took into account the preparatory, programming and anticipatory neural processes underlying it. Every goal-oriented action is based on a *Motivation* that attracts our *Attention*, and this cannot ignore the biological need to complete a motor task; this need inevitably involves the search for the information necessary for this purpose, which, in the scheme, is known as *Afferent Synthesis*.

There are many neural structures that together help organize these processes, including, for example, our past experience, i.e. the *Storage Memory*. At the convergence point of these processes, the *Decision-making* that leads to the *Action* arises: it flows into the contemporary elaboration of an *Action Program* and of an *Action Acceptor*, i.e. of an apparatus for predicting the actually obtained results. The circular process ends only if there is consistency between the *Program* and the *Acceptor*. In this scheme, the function is presented as a complex activity, which is carried out thanks to the joint work of an entire system of organs, each of which becomes part of this *Functional System*.

Within the *Functional System*, a function can be identified as the result of the interaction of structures that organize themselves in different ways to achieve a given biological target. We can hardly be aware of these processes, especially when we organize movements already well learned and automated, such as running. If we are experiencing a moment of motor satisfaction during an evening race, for example, and we are therefore not very careful about how we are organizing the motor function, however, if we are about to make a "wrong" move, we realize the error; this is certainly the clear sign that the set of sensory feedback that our movement should produce are anticipated, meaning that we previously made a perceptual hypothesis. Thus the *Functional System* defined by Anockin (1968) can be considered a general model of all human behavioral activities, from those apparently simpler (like breathing) to those more complex, such as voluntary movement, language, etc.

The concept of function included in the idea of the *Functional System* seems to be the most useful to the study on human movement and is paradoxically also the most modern, because it is consistent with the most recent studies on the organization of the motor function. In fact, in the last decades, by means of the Positron Emission Tomography (PET), it has been proved that, in the human being, there is a Perceptual-Motor Functional System that combines the observation and the performance of an action. In analogy with the data obtained from the experiments on primates, the localization of the active cerebral areas while observing movements of grasping indicates the activation of two areas of the left hemisphere: one located in the superior temporal sulcus, and one in the caudal portion of the inferior frontal gyrus, a region traditionally considered responsible for the language, namely Broca's Area. The latter and its counterpart in the right hemisphere include the Brodmann areas 44 and 45, which are in the opercularis and triangularis portion of the inferior frontal gyrus of the brain's dominant hemisphere. Brodmann area 44 in human finds its counterpart in the F5 area of primates, where the *Mirror Neuron System* has been identified.

Early studies showed that this neural system was activated not only during the performance of actions but especially when they were observed (Gallese et al., 1996; Rizzolatti et al., 1998). Subsequently, it has been shown that mirror neurons have visual-motor properties, are sensitive to motor acts related to a target (Umiltà et al., 2001), but can also be activated by sounds involving actions (Keysers et al., 2003; Kohler et al., 2002). Several PET studies have been carried outlooking for a*Mirror Neuron System* in humans, (Grafton et al 1996; Rizzolatti et al., 1998) by definitively demonstrating that the Broca's area is activated when the subject observes, imagines, and imitates the examiner during an extremely precise hand grip; the Broca's Area could then contain a neural system similar to that of mirror neurons identified in primates (F5 Area).

In contrast to the classic interpretation of the Broca’s Area as an area of exclusive linguistic functionality, recent studies have shown that it contains representations of the actions of the hand and orofacial gestures. The Broca's Area and its counterpart in the right hemisphere were then attributed multiple functions, so much so that it was considered a real functional system, a widely used neural network (Bookheimer, 2002); in fact, it is very likely that the Broca's Area is part of overlapping subsystems supporting various functions, including motor images (Binkofski et al., 2000; Gerardin et al., 2000), handling and grasping objects (Binkofski&Buccino, 2004), and motor programming and planning (Rushworth et al., 2001). The Broca's Area is also activated when learning grammatical rules, distinguishing language sounds, producing words, estimating time intervals, and reproducing rhythms (Bookheimer, 2002). Therefore, it seems to be the interface between action and perception even in non-verbal functions. It could then be a bridge between implicit and explicit communication, the central neural network in the organization of the Perceptual-Motor Function (Nishitani et al., 2005; Fadiga et al., 2009). To confirm this hypothesis, an interesting study has analyzed the performance of patients affected by frontal aphasia, and therefore by injury to the Broca's area, in rearranging figures representing sequences of human actions. The study has fully demonstrated that these patients, who are not affected by apraxia, have a specific impairment in their ability to correctly code the human actions observed (Fazio et al., 2009).

Verbal instructions in the organization of the Perceptual-Motor Function

Understanding the role that the cerebral areas, classically defined as language areas, play in decoding the action, has provided an up draught to scientific research, so much so as to lead to investigate the Perceptual-Motor Function also by observing the link between verbal instructions and motor learning. From the discovery of *Mirror Neuron System*, several hypotheses have been raised, the most suggestive of which states that the F5 area would represent a brain area from which the human faculty to use verbal language would have developed (Rizzolatti&Arbib, 1998). Recent studies (Rizzolatti et al., 2001, 2002, 2004; Umiltà et al., 2001) seem to confirm this hypothesis, tracing a phylogenetic path that from gestural communication, through several stages, concludes with verbal exchange.

If the role of the Broca's Area in recognizing actions that are already part of the observer's repertoire has been extensively demonstrated, (Skipper et al., 2007; Zhang et al., 2018), the role it plays in the learning of new movements has not been yet understood; in other words, we still do not know what kind of contribution the verbal instructions can give to the organization of the Perceptual-Motor Function. It has been shown that different verbal instructions, when compared, involve different types of motor function organization, both in healthy subjects (Prapavessis et al., 1999, 2003; McNair et al., 2000; Cowling et al., 2003; Haguenauer et al., 2005; Oñate et al., 2005) and in patients with neurological diseases (Fok et al., 2011). Moreover, a recent study (Welling et al., 2017) has focused on the comparison of the effects of different verbal and visual feedback in the performance of a counter-movement jump.

In particular, a sample divided into three groups, composed of forty professional athletes, was provided with (in sequence): an external verbal focus ("jump as high as possible after landing, by pushing on the platform as hard as possible") where the focus was on the platform; an internal verbal focus ("jump as high as possible after landing, and extend your knees as quickly as possible after landing") where the focus was on the body; video instructions ("you will watch a video of an expert jump; try to imitate the jump in the best possible way") where the focus was on the imitation. The results showed that both the internal and external focus involves an improvement in the motor function organization, and this does not occur with video instructions. Moreover, only the group that received the internal focus retained the improvement in the one week follow-up.

Conclusion

The study of the Perceptual-Motor Function must be seen as the activity of the whole organism to adapt to the environment in which it lives, where the perceptual act is a behavioral act, that guides the motor action. We have examined the role of verbal instructions as part of the Perceptual-Motor Function in the correction of previously learned movements. We also considered their role in learning new movements. From what has emerged, it is clear that there is a need for a scientific study aimed at understanding how and how much verbal instructions can impact the organization and learning of the Perceptual-Motor Function.

Language probably plays an important role in improving the previously learned action, but there is still no evidence of how effective it can be in the early stages of the learning of actions that do not belong to the subject's motor repertoire. The final consideration concerns the role of the movement experts which, during the teaching of certain activities, should orient the focus of the action consciously through explicit thoughts, in the attempt to perform the motor task (Benz et al., 2016), where the focus on instruction must be based on its experiential content and not on the merely indicative one.

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