THE CEREBRAL LOCALIZATION OF EXECUTIVE FUNCTIONS

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ABSTRACT

Executive Functions (EFs) are a complex neuropsychological tool that can lead all action of daily-life indipendently from age. The attempt to associate specific regions of the central nervous system (CNS) with specific sensory functions, motor and cognitive skills is one of the most recurring themes in the history of neuroscience. The concept of cerebral localization of mental activities started from the formulations of beginning phrenologists in Nineteenth century, passing through the holistic conceptions and antilocalization that marked some periods of the Twentieth century, until the beginning of the new millennium, characterized by the enormous popularity of the techniques of functional neuroimaging and the success of research programs aiming to create a real functional cartography of the human cerebral cortex.

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Introduction

Executive Functions (EFs) are a complex neuropsychological tool that can lead all action of daily-life indipendently from age. The attempt to associate specific regions of the central nervous system (CNS) with specific sensory functions, motor and cognitive skills is one of the most recurring themes in the history of neuroscience. The concept of cerebral localization of mental activities started from the formulations of beginning phrenologists in Nineteenth century, passing through the holistic conceptions and antilocalization that marked some periods of the Twentieth century, until the beginning of the new millennium, characterized by the enormous popularity of the techniques of functional neuroimaging and the success of research programs aiming to create a real functional cartography of the human cerebral cortex[1-5].

Certainly, 150 years after Paul Broca's discovery, conventionally regarded as the birth certificate of neuropsychology, the consensus is unanimous on the fact that selective lesions of different areas of the human cerebral cortex can produce cognitive and behavioral disturbances equally selective. However, the debate about the limits of this selectivity is still on. In particular, it remains the question of whether faculties such as intelligence or high-level cognitive processes can be allocated with a certain precision in specific areas of the cortex[1-5].

In this context, the case of the EFs is paradigmatic, but also in some paradoxical ways. In this case, the location of the function historically precedes the same formulation of the construct.

If indeed the notion of EFs has established itself relatively recently, the disorders we call today Dysexecutive were already known and labeled as frontal lobe syndrome with the clear implication of an explicit localization in the frontal cortex, and in particular in its anterior part, the cortex prefrontal. Indeed, it can be said that in the last twenty years the consensus on an inevitable correspondence between disorders dysesecutive and prefrontal lesions both went hand in hand. Today it is believed rather that the EFs are implemented in multiple distributed circuits, each of which includes connections to some portion of the prefrontal cortex[1-5].

The idea of the prefrontal cortex as a control system can be traced back to Lurija, who considers the higher mental faculties as the result of the operation of functional systems that involve multiple areas interconnected cortical and subcortical. In this regard, the prefrontal cortex is part, together with the cerebellum e to some subcortical nuclei, a system for planning, regulating and monitoring actions voluntary. This idea was based however on clinical observations about the relationship between frontal lesions and disorders of these integrative and control functions. Despite the validity of these evidences has been questioned, above all for their qualitative nature, Lurija's ideas have influenced the subsequent cognitive models of the front operation and in the prefrontal cortex the possible location of the supervisory system supervisor (SAS); the dysexecutive symptoms of the frontal patients are then attributed the inability of a damaged SAS to generate new plans and new voluntary actions in all those situations not habitual, in which the routine and automatic selection of actions is not satisfactory (Figure 1).

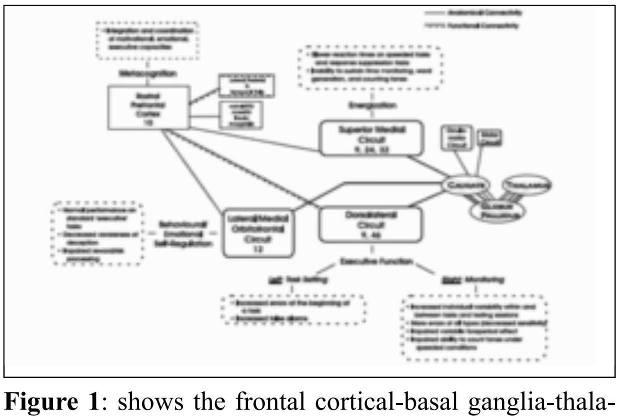

Figure 1: shows the frontal cortical-basal ganglia-thalamic circuits, supporting the fractionation of the frontal functional regions.

The idea of one direct correspondence between frontal cortex and SAS is based on evidence that only those with lesions fronts fail in classic EFs tests such as the Wisconsin Card Sorting Test (WCST), the Stroop test and the Tower of London[1-12]. However, there are good theoretical and empirical reasons for dissociating at least partially the concept of executive function from the functioning of the prefrontal cortex. In 1988 it has been proposed the term dis-executive syndrome in place of that of lobe frontal syndrome frontal, to allow to study the nature and cognitive-behavioral characteristics of patients with executive disorders separately from the delicate problem of the possible cerebral localization of EFs[12-15].

On the other hand, patients with focal frontal lesions do not necessarily show impaired performance in these tasks, while abnormal performance can be found in patients without evidence of frontal damage. In fact, although the activation of different components of the prefrontal cortex is verify with a certain regularity, other regions are also constantly activated, including the parietal cortex lateral and medial-posterior and various subcortical centers. So, although it is indisputable that the frontal lobe is involved in the EFs, it is risky to consider the prefrontal cortex as such as the executive center of the brain, because it is more plausible that the EFs are the result of the operation of several interconnected circuits, which include different areas of the frontal cortex with their cortical and subcortical connections. The simplistic equation between EFs and prefrontal cortex functions has therefore been criticized. basic considerations of empirical order, but there are two observations to make[16-28].

The prefrontal cortex constitutes about 30% of the entire cortex; the earlier frontal areas are specifically developed in the human brain, but their greater volume seems to be due to an increase in the size of the white substance, rather than the gray substance[29-35]. In addition, the neurons of the prefrontal cortex have the distinction of having a greater density of spines and dendrites than the other cortical areas[36-48]. These differences in volume and density are the reason for the complexity of human cognition, in particular of executive functions.

In man the period of childhood and adolescence is more protracted in all other living species and it is in this period that the development of the frontal lobe, in particular of the prefrontal buck, is more active. The different organizational models of the prefrontal areas all propose an unsustainable functional segregation of the cortical areas occupying the three surfaces of the cortex: lateral, orbital and medial[49-53]. The lateral prefrontal cortex is the neural substrate of the following executive processes: set -shifting (active and cognitive flexibility), working memory - ability to keep active a mental representation (perceptive verbal) to perform complex tasks -, planning, strategic behavior, categorization (abstraction). Although the working memory is a conceptual construct connected to a network of both front and back structures, the crucial anatomical portion for this process is the lateral cortex cortex.

Furthermore, the lateral prefrontal areas are also involved in attenuating through a modulation of the posterior cortical areas. The orbital portion of the prefrontal cortex is instead connected to activities in which the subject has to make a choice between a series of possible alternatives. It is divided into two portions, medial and lateral: the medial portion is involved in maintaining in memory the association between a family stimulus and a gratifying response, while the lateral portion has a specific role in suppressing a habitual behavioral response, persuading it with a response different more suited to the context[54-60].

This portion of the prefrontal cortex is connected to the limbic system and the subcortical structures, therefore it has a fundamental role in the management of primary thrusts, instincts and in the emotional sphere. The medial prefrontal region has among its functions that of detect errors and resolve divergent trainings conflicts. The circuits of the medial prefrontal cortex are important to the sustained attention, but above all in the behavioral initiative. The medial lesions of the frontal lobes are those that constitute the cortical apparatus that regulates the state of activity and allow the initiative. The same ones play a fundamental role in the maintenance of some conditions of human conscious activity: the preservation of the necessary cortical tone and the modification of the state n basis for the immediate tasks of the subject. All these data are supported by anatomo-clinical evidence in which the effects, in part specific, of the frontal lesions have been studied. Orbitofrontal syndrome. An orbitofrontal damage is associated with disinhibition, inappropriate behavior, personality changes, irritability, emotional lability, absence of touch and distractibility[61-69].

They are subjects incapable of responding appropriately to social stimuli. Furthermore, orbitofrontal exposure is phylogenetically and ontogenetically earlier than development.

It is linked to basic adaptation tasks: emotional regulation and behavioral inhibition[70-74].

Moreover, when the dorsolateral circuit is compromised, there is an inability to organize a behavioral response to new and complex stimuli. Several researchers have noted that this syndrome is characterized by perseverations, syndrome of utilization (difficulty to make functional use of the object evoked by its presence), echopraxis and echolalia. Numerous experimental evidences suggest that there is at least another cortical region involved as well as the prefrontal area and the related cortical and subcortical circuits. This area is the posterior parietal cortex, which is considered relevant in the reconfiguration of the associations between stimuli and responses or in the management of stimulus-guided behavioral adjustments[75-80].

In a recent neuroimaging study for example, the implementation of cognitive control in response to the interchange of the experimental task produced significant modulations in the dorsolateral prefrontal cortex, in the anterior cingulum and in the posterior parietal cortex. The type of conflict, at the level of stimulus or response representation, selectively modulated the parietal cortex and the anterior cingulate, independently of the prefrontal cortex. Compatibly with the idea that the parietal cortex, together with the cingulum, has a role in detecting the conflict in signaling it to the lateral prefrontal cortex in order to increase cognitive control, increase the activity in the parietal cortex and in the cingulate predicted an increase in activity in the prefrontal cortex and an improvement in performance in subsequent trials[81-87].

To date, knowledge the neurological development allow us to highlight only the macroevoluation ontogenetics of neural circuits; moreover, the localizations of the cognitive processes are rather sketched and they are also modified according to the peculiar characteristics of each person. It is believed that in the future developmental neuroscience will try to grasp the relationship between cognitive and neurological development in an integrated way, through neuroimaging tools and experimental neuropsychology[81-87].

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