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There are Two Different Dysexecutive Syndromes

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Abstract

The idea of "executive function" has become a fundamental concept in contemporary neurosciences. However, some disagreement remains around the question of unity or diversity (non-unitary) of executive functions and different points of view have been proposed. In this paper it is suggested that two major types of executive dysfunction syndromes can be separated: (a) Metacognitive executive dysfunction syndrome associated with dorsolateral frontal damage; and (b) Motivational/emotional executive dysfunction syndrome associated with orbitofrontal and medial frontal pathology. The first one is characterized by disturbances in intellectual abilities ("intelligence"), whereas the second one relates to impairments in behavioral control (disinhibition, impulsivity, etc.). Contemporary neuroimaging studies support this proposal.

Keywords: Dysexecutive syndromes; Prefrontal cortex; Executive functions

Introduction

The idea of "executive function" has become a fundamental concept in contemporary neurosciences [1]. The observation that the frontal lobes are involved in regulatory behaviors, including planning, self-monitoring, problem solving, inhibiting responses, strategy development and implementation, and working memory, resulted in the comprehensive term "executive function." Luria [2,3] first suggested the idea of executive function. He distinguished three functional units in the brain: (a) arousal-motivation (limbic and reticular systems); (b) receiving, processing, and storing information (postrolandic cortical areas); and (c) programming, controlling, and verifying activity (frontal lobes) [2]. Luria mentions that this third unit has an executive role. Lezak [4] introduced the term as the dimension of human behavior that deals with "how" behavior is expressed. Initially, executive functions were conceptualized as having four components: The abilities of goal formation, planning, carrying out goal-directed plans, and effective performance. Repovs and Baddeley [5] grouped these behaviors into cognitive domains that included problems in planning, organizing behaviors, disinhibition, perseveration, reduced fluency, and initiation. Baddeley coined the term "dysexecutive syndrome."

Historically Phineas Gage became the most typical example for frontal lobe dysfunction, and the dysexecutive syndrome became synonymous with frontal lobe pathology [6]. Harlow [7] described Phineas Gage as a responsible foreman for a railroad company who suffered a tragic accident in which a tampering rod was projected through his frontal lobes when supervising construction on the railroad across Vermont. After the accident, he is described as "profane," "irascible," and "irresponsible." Interestingly, most of the disturbances reported in Phineas Gage refer to behavioral/emotional disturbances, or more exactly, disturbances in coordinating cognition and emotion/motivation. Harlow [8] described significant emotional and behavioral abnormalities in Phineas Gage but emphasized that no intellectual impairments were observed; he explicitly underlined that neither his memory nor his intelligence were compromised by the brain lesion. Harlow [7] stated that the "equilibrium or balances so to speak, between his intellectual faculties and animal propensities seem to have been destroyed. He is fitful, irreverent, indulging in gross profanity (which was not previously his custom), manifesting little or no deference for his fellows, and impatient of restraint or advice when it conflicts with his desires" (p. 389). Important to note, the frontal damage in Phineas Gage involved the orbital and medial aspects, but not the prefrontal dorsolateral area [9,10].

The prefrontal lobe has extensive connections to subcortical and limbic system areas [11,12] and even its orbital portion could be regarded as an extension of the limbic system. The prefrontal cortex has also been identified as the core site for the integration of mood and cognition [13], and as a matter of fact, many of the disturbances observed in patients with prefrontal pathology (for instance, Phineas Gage) could be interpreted as disturbances in emotional control.

Currently, frontal lobe function research is utilizing functional brain imaging techniques to pinpoint the participation of different brain areas in executive function tasks [14]; thus, brain regions that contribute to dysexecutive syndromes may prove to be more multifunctional [15]. Functional imaging has demonstrated that adults and children with focal, especially frontal damage display similar executive function disturbances, such as attentional deficits, inability to inhibit a response, and impersistence of activity [16].

One or Several Executive Functions?

Some disagreement exists around the question of unity or diversity (non-unitary) of executive functions [17-21]. It is not easy to find a particular unitary factor saturating the different executive function tasks, and different proposals have been presented.

Behavior inhibition has been considered as the potentially single factor responsible for successful performance in different executive tests [22] alone or in combination with working memory [23]. Salthouse [24,25] suggested that reasoning and perceptual speed could represent the underlying factors related to all executive functions. Salthouse [25] observed that performance on two common tests of executive functioning, the Wisconsin Card Sorting Test [26,27] and the Controlled Oral Word Association Test [28], were strongly correlated with reasoning ability and perceptual speed.

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Other authors challenge the existence of such a unitary factor, suggesting the executive function includes a diversity of subcomponents. Godefroy et al. [29] emphasized that certain frontal lobe patients perform well on some tests purported to assess executive abilities but not on others. Factor analysis has also supported that executive functions include several subcomponents [30,31]. For example, Testa et al. [32] performed a factor analysis of 19 executive function tests administered to a nonclinical sample of 200 adults, and found 6 independent factors: prospective working memory, set-shifting and interference management, task analysis, response inhibition, strategy generation and regulation, and self-monitoring and set-maintenance. Noteworthy, correlations among different executive tests are frequently moderate or low, and many times lacking statistical significance [33-35], suggesting that they measure different underlying factors.

Some authors have preferred to take an intermediate position. Miyake et al. [36] studied three often-postulated aspects of executive functions (shifting, updating, and inhibition) and concluded that, although they are clearly distinguishable, they do share some underlying commonality. Based on the results of their study, the authors stated that executive functions are "separable but moderately correlated constructs" thus suggesting both unitary and non-unitary components of the executive system. By the same token, several authors have suggested different subcomponents of executive functions [4,37-43].

Two Fundamental Dysexecutive Syndromes

It seems evident that patients with prefrontal pathology can present intellectual abnormalities (problem solving difficulties, abstraction defects, etc.) and also emotional/ behavioral changes, as clearly illustrated in Phineas Gage classical case. Consequently, it may be conjectured that there are two different, but closely related types of executive functions [44-46] and two different dysexecutive syndromes; they probably appeared at different historical moments [47] and develop in children at different age [48].

The idea that there are two basic executive functions has been suggested by different authors; for instance, a distinction has been proposed between the "cool" cognitive aspects of executive functions, which are more associated with dorsolateral regions of the prefrontal cortex, and the "hot" affective aspects, which are more associated with the ventral and medial regions [49]. This hot/cool distinction has been applied to the development of executive functions in children [50]; it was observed that whereas cool (metacognitive) executive functions significantly correlated with general intellectual ability ("intelligence"), hot (emotional/motivational) executive functions are not related to general intellectual functioning (verbal mental age and performance mental age).

It could be argued that the use of the terms "cool" and "hot", however, could generate conflict, because behavioral symptoms could indeed be regarded as "cool" or "hot". As a matter of fact, the prefrontal behavioral symptoms could also divided into two syndromes: apathy, withdrawal, decreased communication, and depression as cingulate/ prefrontal medial syndrome (limbic symptoms-"cool"); and, on the other hand, impulsivity, disinhibition, personality disorders, aggressiveness, and other similar manifestations as orbitofrontal syndrome (symptoms paralimbic-"hot").

These two fundamental executive functions are:

(1) "Metacognitive executive functions" which include temporality of behavior, problem solving, abstracting, planning, anticipating the consequences of behavior, strategy development and implementation, and working memory (the usual understanding of executive functions, generally measured in neuropsychology executive functions tests); these are abilities mostly related with the dorsolateral area of the prefrontal cortex [51]. As a matter of fact, the dorsolateral prefrontal cortex has been observed to participate in planning, abstracting, problem solving, and working memory tasks. Using fMRI dorsolateral prefrontal activation has been found in tasks such as solving the Tower of Hanoi [52], Controlled Word Association Test (letter fluency) [53], working memory [54], and solving the Wisconsin Card Sorting Test [55].

(2) "Emotional/motivational executive functions," which are responsible for coordinating cognition and emotion. That means, the ability to fulfill basic impulses following socially acceptable strategies. Phineas Gage can be considered as the most typical example of a disturbance in emotional/ motivational executive functions. In this case, what is most important does not necessarily include what the best conceptual and intellectual result is, but what is in accordance with personal impulses [56]. In that regard, the core function of the prefrontal lobe is to find acceptable justifications for limbic impulses. Following socially acceptable strategies actually involves inhibition of selfish or unsociable basic impulses in the first place, but not necessarily arriving at the best conceptual solution. The ventromedial areas of the prefrontal cortex are involved in the expression and control of emotional and instinctual behaviors [44,45]. This function is related with so-called "inhibitory control" of behavior [57]. Clinical evidence [2,51] as well as experimental research [58,59] suggest that the neural substrate for this inhibitory function resides mainly in the medial and orbital portions of the prefrontal cortex. Fuster [45] points out that "The apparent physiological objective of inhibitory influences from orbitomedial cortex is the suppression of internal and external inputs that can interfere with whatever structure of behavior, speech, or cognition is about to be undertaken or currently underway" (page 382).

Noteworthy, research has shown that emotional executive functions (such as attention control) develop earlier in life (during the 1st year), before the development of metacognitive executive functions (such as planning and verbal fluency), which develop around the age of 3 and are correlated with the development of a grammatical language [48].

Metacognitive Executive Dysfunction: Dorsolateral Syndrome

It has been suggested that the dorsolateral circuit is the most important to executive functioning [60]. The most frequently observed deficit is an inability to organize a behavioral response to novel or complex stimuli. Symptoms are on a continuum and reflect capacity to shift cognitive sets, engage existing strategies, and organize information to meet changing environmental demands.

Various researchers, including Luria [2], have noted perseveration, stimulus-bound behavior, echopraxia, and echolalia. Lateralization has been noted in executive dysfunction [61]. Ventral and dorsal portions of prefrontal cortex are believed to interact in the maintenance of rational and "non-risky" decision making [62]. According to Fuster [45,63], the most general executive function of the lateral prefrontal cortex is the temporal organization of goal-directed actions.

Motivational/Emotional Executive Dysfunction: Orbitofrontal and Medial Frontal Syndrome

Orbitofrontal damage has been associated with desinhibition, inappropriate behaviors, personality changes, irritability, mood liability, tactlessness, distractibility, and disregard of important events [51]. Patients with this syndrome are unable to respond to social cues. Noteworthy, it was observed by Laiacona et al. [64] that these patients have no difficulty with card sorting tasks. Eslinger and Damasio [65] coined the term "acquired sociopathy" to describe dysregulation that couples both a lack of insight and remorse regarding these behaviors.

The orbitofrontal cortex appears to be linked predominantly with limbic and basal forebrain sites. Medial frontal lobe damage causes apathy or abulia (a severe form of apathy). Acute bilateral lesions in the medial frontal area can cause akinetic mutism, in which the individual is awake and has self-awareness, but does not initiate behaviors [66]. According to Fuster [45,63], the ventromedial areas of the prefrontal cortex are involved in expression and control of emotional and instinctual behaviors. Furthermore, the cingulated gyrus (medial frontal region) is closely related as well to the emotional/ motivational dysexecutive syndrome. Damage in the anterior cingulated gyrus causes apathy or abulia.

It seems evident that the dysexecutive (prefrontal) syndrome can have rather different clinical expressions (metacognitive and emotional/ motivational) depending upon the specific location of the damage.

There is solid evidence to assume that two different prefrontal systems support these two executive function subtypes. For instance, Gläscher et al. [67] used voxel based lesion symptom mapping (i.e., method and software for analyzing relationships between behavioral deficits in neurological populations and lesion sites associated with those deficits) in 344 individuals with focal brain lesions, including 165 involving prefrontal pathology; a comprehensive neuropsychological test battery was administered to all participants. It was demonstrated that there are two distinct functional-anatomical networks within the prefrontal cortex: (a) one associated with cognitive control (that is, "metacognitive executive functions," including response inhibition, conflict monitoring, and switching), and supported by the dorsolateral prefrontal cortex and anterior cingulate cortex; and (b) a second functional-anatomical network associated with value-based decision making ("emotional/motivational executive functions"), which included the orbitofrontal, ventromedial, and frontopolar cortex.

Conclusion

Regardless that the concept of executive function is relatively new in neurosciences, it has become a most important idea in understanding human behavior and cognition. There is not a general consensus yet if there is a single unitary factor underlying executive functions; or rather, "executive function" includes a diversity of subcomponents, and indeed there are diverse executive functions.

Two major anatomical systems have been demonstrated in the frontal lobe: dorsolateral and orbito/medial, associated with rather different neuropsychological syndromes; the first one is characterized by disturbances in temporal organization of behavior, problem solving difficulties, abstracting and planning impairments, and working memory defects (metacognitive executive dysfunction syndrome); the second is characterized by defects in inhibitory control (emotional/ motivations executive dysfunction syndrome). The first one is associated with disturbances in intellectual abilities ("intelligence"), whereas the second one relates to impairments in behavioral control (disinhibition, impulsivity, etc.). A similar distinction has been proposed by different authors; for instance, it has been mention the distinction cold/hot executive functions [49] associated with two different frontal systems (dorsolateral and ventral/medial) and impaired in different ways in cases of focal frontal pathology.

This proposal of two dysexecutive syndromes may have significant clinical consequence from the assessment/testing point of view: some specific tests (e.g., impulsivity inhibition tests, such as the Stroop test) are assessing motivational/emotional executive dysfunction; whereas other tests (e.g., card sorting and planning tests) are evaluating metacognitive executive dysfunction. By the same token, manage/ intevention has to be different, targeting behavioral disorders in the first case, and cognitive impairments in the second one.

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