

# Rehabilitation of executive functions: Implications and strategies

Rehabilitación de las funciones ejecutivas: implicaciones y estrategias  
Reabilitação das funções executivas: Implicações e estratégias

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## Abstract

Executive Functions (EF) concern a range of abilities including problem-solving, planning, initiation, self-monitoring, conscious attention, cope with new situations and the ability to modify plans if necessary. It's a high cognitive function that is crucial for a person to get engaged and maintain daily activities whilst keeping a good quality of life. Problems in the EF were formerly known as Dysexecutive Syndrome (DS). There are many models concerning DS, although the literature on the subject still remains unclear. Several works appoint the effects brought by elderly life, as well as abuse of drugs and some psychopathologies. These factors are known to increase the distress of the frontal circuits and that could be associated to executive deficits. The effects of DS would compromise individuals in day-to-day routi-

ne, academic, social and labor fields. There is a growing body of studies trying to determine the causes, implications, associations and the best way to take care of these effects. This work intends to review DS, focusing on the most important fields related to this area, such as psychopathology associations, cognitive reserve, assessment and cognitive rehabilitation programs.

*Keywords (MeSH Terms):* Executive functions, rehabilitation, cognitive reserve and neurobehavioral manifestations

## Resumen

Las funciones ejecutivas constituyen un conjunto de habilidades que incluye la resolución de problemas, la planificación, la iniciación, el autocontrol, la conciencia ante situaciones nuevas y la capacidad de modificar los

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planes si es necesario. Se trata de funciones de alto nivel cognitivo, que son cruciales para que una persona mantenga sus actividades diarias y para la promoción de una buena calidad de vida. El déficit en estas funciones se conoce como síndrome disejecutivo (SD). Hay muchos modelos teóricos sobre SD; sin embargo, la literatura no es muy clara en relación con los componentes involucrados ni con la forma de investigar y resolver este problema. Varios estudios muestran que la edad, el consumo de sustancias y la psicopatología pueden afectar a algunas de estas funciones a través de daños en los circuitos frontales asociados a ellos. El efecto de este daño puede poner en peligro las actividades rutinarias del día a día, imponer dificultades en la socialización y afectar su vida laboral. Hay un cuerpo creciente de estudios que tratan de determinar las causas, consecuencias y modelos que son capaces de dar cuenta de estos efectos y promover estrategias de tratamiento más eficaces. Este artículo pretende hacer una revisión de la SD, centrándose en los aspectos relacionados más importantes, tales como las comorbilidades, la reserva cerebral, la reserva cognitiva y los programas de rehabilitación.

*Palabras clave:* funciones ejecutivas, rehabilitación, reserva cognitiva y manifestaciones neuroconductuales

## Resumo

As funções executivas constituem um conjunto de habilidades que envolvem o planejamento e a resolução de problemas, desde a iniciação, consciência e auto controle de comportamentos frente a novas situações, além da capacidade de modificar tais planos quando necessário. As funções executivas envolvem um alto grau de controle cognitivo e são cruciais para atender as atividades diárias e manter uma qualidade de vida. Os déficits associados a estas funções é denominado Síndrome Disexecutiva (SD). Existem muitos modelos teóricos que procuram elucidar a SD, no entanto, a literatura não é muito clara quanto os componentes envolvidos, formas de investigar e estratégias para resolver estes déficits. Vários estudos apontam que os efeitos da idade, do consumo de substâncias e de psicopatologias podem contribuir para a deterioração de circuitos frontais associados aos déficits executivos, comprometendo ainda mais o funcionamento diário, acadêmico, social e laboral. Existe um vasto campo de estudos visando determinar as causas, implicações, fatores associados e a melhor forma de

lidar com estes efeitos. O presente artigo busca revisar estudos acerca da SD, focando em aspectos centrais como psicopatologias, reserva cognitiva e programas de reabilitação cognitiva.

*Palavras-chave:* funções executivas, reabilitação, reserva cognitiva manifestações neurocomportamentais

## Executive Functions (EF) and psychopathology

In the past, when studying prefrontal damaged patients, researchers noticed there were specific impairments in some functions like initiation, sequencing, flexibility, monitoring, judgment, planning, decision-making and difficulty in learning new tasks (Elliott, 2003; Hughes, 2002; Stuss, 2009). At that time this functional impairment was termed “Frontal Lobe Syndrome”, although some of those patients with problems had their frontal lobes neurologically intact (Sbordone, 2000). Then the incapacity to control these basic cognitive functions at stake became known as the Dysexecutive Syndrome (Wilson & Gilsky, 2009). In this sense, DS is not necessarily associated to frontal lobe injury, but rather a series of deficits in processing, planning, initiating behaviors, maintaining those behaviors, self-regulation and self-monitoring, set-shifting and cognitive flexibility, and meta-cognition.

According to Stuss (2009) there are at least four categories related to frontal functions, but not necessarily related to frontal lobe injuries, as shown in table 1.

Studies have pointed out executive deficits in many psychiatric disorders. For example, polysubstance users and subjects with different psychiatric disorders, including attention deficit hyperactivity disorder (ADHD), Post-Traumatic Stress Disorder (PTSD), schizophrenia and mood disorders, such as bipolar depression (Deckersbach et al., 2010; Eack et al., 2010; Elliott, 2003; Fernandez-Serrano, Perez-Garcia, Perales, & Verdejo-Garcia, 2010; McEwen, 2003; Savitz, Solms, & Ramesar, 2005; Stuss, 2009). Likewise, EF is related to subcortical disorders. Once impaired, EF have been reported to be associated with Parkinson’s disease, progressive supranuclear palsy, Huntington’s disease, Korsaa-

Table 1  
*Different categories of frontal lobe functioning*

Categories	Functions
Energization	Process of initiation and sustaining of any response mode
Executive cognitive functions	Planning, checking the task and adjustment of behavior
Behavioral/emotional self regulatory functions	Required in situations where cognitive analysis, habit, or environmental cues are not sufficient to determine the most adaptive response, a high-level decision making
Meta-cognitive process	Integration of cognition and emotion, aspects of personality, social cognition, consciousness, theory of mind, humor appreciation and self-awareness

Adapt from Stuss (2009)

koff syndrome and dementia caused by inhalation of organic solvents (Sbordone, 2000).

There are many studies showing the neurological effects of these illnesses and their functional losses (Deckersbach, Dougherty, & Rauch, 2006; Leverich et al., 2002; Pavuluri, West, Hill, Jindal, & Sweeney, 2009). In mood disorders, for instance, even during mood episodes, patients have cognitive impairment related with frontal regions, showing reduced performance in verbal memory, cognitive flexibility, coping, meta-cognition and self-regulation, especially when compared to healthy subjects (Deckersbach, Dougherty, Savage, et al., 2006; Deckersbach et al., 2004; Dittmann et al., 2007).

The substance-related disorders are also associated to executive impairments such as cognitive flexibility, theory of mind, decision-making and processing speed (Barry & Petry, 2008; Fernandez-Serrano, Perez-Garcia, & Verdejo-Garcia, 2011). Again the most frequent hypothesis is the hypofrontality of brain structures and networks (Kim, Kwon, & Chang, 2011; Uekermann, Channon, & Daum, 2006; Uekermann, Channon, Winkel, Schlebusch, & Daum, 2007).

Actually, the disease with the largest range of rehabilitation interventions is schizophrenia, with significant brain volume losses observed in these patients (Pfefferbaum, Sullivan, Hedehus, Moseley, & Lim, 1999; Zipparo et al., 2008). Furthermore, patients with schizophrenia demonstrated a significant decline in social skills, increasing the need for proposals with more comprehensive interventions. These interventions must combine neurocognitive and psychosocial components, whose results have shown positive effects on the functioning of these individuals (Kluwe-Schiavon, Sanvicente-Vieira, Kristensen, & Grassi-Oliveira, 2012). In our last session we described some rehabilitation programs for schizophrenia, although before allow us to review the protective factors involved and the measures that evidence such deficits.

### Cognitive and brain reserve

With the implications of DS, researches are pointing towards aspects that could protect the illness development. In this sense, there are two concepts that have gained prominence in discussions, brain reserve and cognitive reserve. On the other hand, while psychopathology is increasing the risk for the deterioration of EF, the cognitive and brain reserve could decrease this risk, for it is concerned with the brain's capacity to actively cope with brain damage through the implementation of cognitive processes (La Rue, 2010; Stern, 2009).

Brain reserve typically refers to specific characteristics of the brain that may vary across individuals, including size (cranial capacity), neurogenesis, neural density and synaptic connectivity. Studies provide evidence that brain reserve may be malleable and suggest that exercise, in particular, may benefit in this way (Siedlecki & Stern, 2009). Researchers have already supported that education increases the growth of synapses in an infant or child. In addition, the effect of exercise with virtual reality on clients with traumatic brain injury reported improvements in some cognitive measures (Cotman & Berchtold, 2002; Grealy, Johnson, & Rushton, 1999; Katzman, 1993).

Cognitive reserve refers to the brain's capacity to cope with problems utilizing other cognitive re-

sources. As a consequence, two individuals with the same degree of structural brain reserve might adapt to brain injury in a more or less successfully manner if one has a bigger amount of cognitive reserve, that is, a bigger variety of cognitive processes to enlist or to use in compensation (La Rue, 2010). Neural implementation of cognitive reserve can be divided into neural reserve and neural compensation (Siedlecki & Stern, 2009). According to Stern, 2009, the first refers to the differential efficient circuits of synaptic connectivity, while the neural compensation refers to the recruitment of brain areas not typically used by individuals without brain pathology to compensate for brain damage, which may reflect the use of alternative strategies.

Increased cognitive reserve may help in recuperation and compensation for the injury through both neural reserve and neural compensation. These findings allow us to think about the implications in terms of neuroplasticity and cognitive rehabilitation. Once it is probable that DS problems are associated positively with some structural damages, people with brain reserve have something like “fat to burn”, while those with cognitive reserve can handle better and find different ways to figure out a problem. Sustaining this findings, some data from individuals with high level functioning in activities –such as reading, visiting friends, going to movies and restaurants, walking and doing exercise– have a smaller risk of developing dementia (Scarmeas, Levy, Tang, Manly, & Stern, 2001). Other studies showed that clients with a history of premorbid disease suffered greater post-injury cognitive declines (specifically in measures of fluid ability) than did those without history of premorbid disease (Ropacki & Elias, 2003). On the other hand, as previously mentioned, psychiatric disorders are capable of damaging brain reserve, as seen in schizophrenia when loss of gray matter may reach 3% of the total volume of the entire brain, specifically 3.5% in the frontal lobe (Pfefferbaum et al., 1999; Zipparo et al., 2008). In conclusion, the more brain and cognitive reserve a person has, the smaller the chances are that a psychopathology, a brain injury, or even another unknown cause, will affect their EFs.

### Assessing and evaluation of executive dysfunction

To choose the best therapeutic program, a good neuropsychological assess is necessary based on three basic goals: measuring, diagnostic and the interpretation of each measuring (Miller, 1992). The neuropsychological tests must individually discriminate the cognitive components (measuring), like planning or auto-monitoring, individually and then, indicate where the errors are concentrated (diagnostic). The last part consists in deciding which will be the focus of rehabilitation (interpretation) (Miller, 1992).

However, to establish the diagnosis when a person is not functioning effectively - because they are impulsive, unable to plan, or incapable of maintaining task goals – they are not always straightforward when it comes to self-reporting (Burgess, Alderman, Evans, Emslie, & Wilson, 1998; Evans, 2009). Moreover, in practice it could be difficult to determine all aspects involved in behavioral problems because of the complaint stated above. For instance: poor attention or specific working memory deficits are often the first symptoms to catch our attention. As a consequence, the person’s self-monitoring increases, and hence the client fails to notice problems as they occur. Another manifestation of executive deficit would be impulsivity: for some clients the problem is not so much an inability to look ahead or anticipate consequences, but the incapacity to see the negative consequences of actions in the decision-making process, as considering choices which seem apparently irrelevant as a result of their impulsivity (Evans, 2009; Oddy, 2009).

In this sense, some authors discuss about the ecological validity of a reasonable number of neuropsychological tests (Chaytor & Schmitter-Edgcombe, 2003). By “ecologic” it is possible to understand how representative the test is with the life of this subject. Some authors proposed that most tests do not illustrate the truth of the clinic manifestation; probably because these assessments happen all at once in day-to-day life, but in standard tests (non-ecological) they are observed separately

(Alderman, Burgess, Knight, & Henman, 2003; Shallice & Burgess, 1991).

The Zoo Map and the Multiple Errand Test are two examples with great ecological validity (Alderman et al., 2003). The client should complete a list of tasks simultaneously. It requires a planning capacity and also a good executive ability to do all the tasks. It mixes simple tasks, making a dual-task exercise, especially the Multiple Errands, due to its results of patterns of errors. This idea is closer to the real-world situation than other tests which can be excellent EF tests, but not to the ordinary moves we do every day (Eslinger & Damasio, 1985; Shallice & Burgess, 1991). The Rivermead Behavioural Memory Test is another valid ecological test used to assess everyday memory problems, detecting moderate-to-severe impairments, yet subtle memory deficits may go undetected for some clients who achieve a score within the normal range (Wills, Clare, Shiel, & Wilson, 2000).

Actually the most modern programs of rehabilitation consider the functional assessment as the most revealing. They analyze the performance of the client in the situations that the deficit is present and notice the exact stage the person breaks down (Evans, 2001).

By focusing on the gradual increase of the client's autonomy, a greater number of hits will be achieved through rehabilitation (Fish, Manly, & Wilson, 2009).

Another method of assessment that has grown in the last years is the use of Virtual Reality (VR), which has also been used for rehabilitation goals (Carelli, Forman, & Mantyla, 2008). The technology of VR has been found as a viable treatment and assessment in several contexts (Hoffman et al., 2008; Rothbaum et al., 1999). VR has been used as a way to increase the ecological validity of the tests, since in the virtual world it is possible to simulate a wide range of possibilities and situations. Instead of simulating a conventional activity, the V-STORE (Lo Priore, Castelnovo, & Liccione, 2003) simulates a shop where they have to pick up products at the Virtual Action-Planning Supermarket simulating a daily life errand (Josman, Schenirderman, Klinger, & Shevil, 2009).

### Rehabilitation of everyday executive functions

Ever since the Supervisory Attention System model (SAS)—proposed by Shallice and Burges—has been established, the everyday functioning is a highly complex and dynamic interaction of automatic routine behavior and a consciously controlled action (Evans, 2009; Jurado & Rosselli, 2007; Tirapu-Ustarrroz, Garcia-Molina, Luna-Lario, Roig-Rovira, & Pelegrin-Valero, 2008). It suggest that the goal of every executive rehabilitation program should be to improve or allow greater autonomy for the individuals in everyday situations, enabling them to solve problems (within its capabilities) rather than being stuck in a vicious cycle in which executive skills are not utilized (Miotto, 2012). Basically, DS rehabilitation programs could be classified in four focuses: (a) restore cognitive functioning, (b) make up the shortfall by internal or external strategies, (c) promote the modification of the environment and (d) pharmacological interventions (Miotto, 2012).

In the prospective memory context, the re-training is a technique in which the client performs a certain activity repeatedly with increasing periods of time between them. This spaced retrieval is a useful and well-known technique for learning information. As long as this is successful, we can strengthen the retrospective memory to provide the necessary support to prospective memory (Camp, Foss, Ohanlon, & Stevens, 1996). It is very useful with individuals with Alzheimer's disease for performing a daily task of prospective memory displayed in a calendar (Fish et al., 2009). In addition, it can give support to an executive component, using the free lanes or integrative approaches, aiming to raise awareness of the difficulties and to increase the use of compensatory strategies (Fish et al., 2009; Fleming & Ownsworth, 2006).

Amongst the daily activities and rehabilitation of the EFs, an efficient and familiar strategy is to positively reinforce changes achieved after a pre-established period, giving priority to the improvement of selective attention, planning and organization of time. Tasks are divided into different stages, each one with its own specifications (showering in less than 20 minutes, getting dressed in less than

5 minutes, e.g.). The weekly performance of each stage is distributed on a schedule of points; each improvement achieved being rewarded at the end of each month. These points may result in a great reward chosen by the individual client, such as a trip out. The idea is that rehabilitation transforms the routine setting into a system that promotes continuous learning (Worthington & Waller, 2009), promoting the modification of the familiar environment. In terms of optimizing time and improving activities already learned, these kinds of strategies have demonstrated good results, but when the client have to plan and develop a sequence of a goal-oriented tasks themselves, prospective memory has been more effective (Oddy, 2009).

Communication impairments can also be associated with executive disorders. Pragmatic abilities required in comprehension of non-literal information in discourse, speech acts, metaphorical sentences and words, among others (Douglas, 2010). There is a model of supported conversation which divides responsibility for the success of the dialogue between the person with the communication deficit and a listener (Corkey & Fairweather, 2009). Videos illustrate the difference between a conversation with two people without disabilities and another in which there is a person with a communication difficulty. This enables the client and the therapist to discuss the capacities or abilities of the characters in the footage – gestures and conversation topics, for example. In addition, they engage in an integrative role play and, finally, in evaluative exercises (Corkey & Fairweather, 2009). This kind of intervention might train the individual to improve their verbal and nonverbal communication enabling them to be more assertive.

Moreover, there are many cognitive training programs being developed to improve the cognitive abilities of people with schizophrenia, specially social and occupational dysfunctions. Neurocognitive Enhancement Therapy (NET) is part of one of these programs. NET is consisted of feedbacks in a support group with cognitive exercises for up to 5 hours each week for 26 weeks, and a weekly social processing group (Bell, Bryson, Greig, Corcoran, & Wexler, 2001). Cognitive exercises involve repeated practices of computer-based exercises for

attention, memory, and executive function (Bell et al., 2001). This program could be linked with a Work Therapy (WT) – a paid work activity in job placements– that aims to promote occupational improvements. In an important study, the author investigated the efficacy of therapy in 65 patients with schizophrenia or schizoaffective disorder that were randomly assigned to NET plus WT or just WT (Bell et al., 2001). After 5 month of follow-up, those patients that received NET+WT showed greater improvements on pretest-posttest variables of executive function, working memory and affect recognition.

In the same way, other computer-assisted cognitive remediation programs that train attention, memory, language and problem-solving, have shown improvement in neurocognitive function (Kurtz, Seltzer, Fujimoto, Shagan, & Wexler, 2009; Kurtz, Seltzer, Shagan, Thime, & Wexler, 2007; Penades et al., 2006). One study with 53 outpatients in the early course of schizophrenia or schizoaffective disorder sought to investigate whether there were differences in neuroimaging (Eack et al., 2010). The author divided two groups, one who received Cognitive Enhancement Therapy (CET), which is an integrated approach to the remediation of cognitive impairment that uses computer-assisted neurocognitive training and group-based social-cognitive exercises. The other group received Enriched Supportive Therapy (EST) that is an illness management approach that provides psychoeducation and teaches applied coping strategies. They found that individuals who received CET demonstrated significantly greater preservation of gray matter volume over 2 years in the left hippocampus, parahippocampal gyrus, and fusiform gyrus, not to mention significantly greater gray matter increases in the left amygdala compared with those who received EST (Eack et al., 2010). More than that, the author suggests that CET may offer neurobiological protective and enhancing effects in early schizophrenia. Interventions such as these have proved a fertile field for research and new forms of treatment and may act in reducing the potential chronicity of schizophrenia.

Deckersbach and colleagues, based on cognitive behavioral therapy, developed a cognitive

remediation therapy that showed lower residual depressive symptoms as well as an overall increased psychosocial functioning in bipolar disorders patients (Deckersbach et al., 2010). The model consists of three separate modules focused on (1) mood monitoring and treatment of residual depressive symptoms, (2) organization, planning and time management, as well as (3) attention and memory and were distributed this order. The first module includes problem solving, increasing awareness of negative automatic thoughts and cognitive restructuring thereof; the second and third focused on organization, planning and time management, so that the patients would make use of schedules and notebooks, keeping daily task lists. They were trained in prioritizing activities, breaking down complex tasks into simpler tasks, and making more realistic time estimations for activities/projects (Deckersbach et al., 2010).

### Conclusions

The study in rehabilitation of the EFs is a challenge to the increasing DS diagnosis. There are numerous casualties, as it affects the individual's academic, social, professional, financial and affective life, that is, DS has a direct negative effect on day-to-day life. More importantly, there is an apparent positive correlation between DS and psychopathology. Amongst these psychopathologies, schizophrenia and bipolar disease are especially relevant due to their chronic characteristics leading to a progressive neurodegenerative framework.

Aiming to enhance understating on the subject, there is a necessity for research gathering not only the knowledge on basic science but also on applicable science. The rehabilitation programs are already successfully managing to diminish the impairments associated with DS, to the point where patients are improving and establishing near-autonomy and a productive work capacity. In spite of this progress, there is still insufficient evidence on the achievement of fully-efficient recovery to pre-morbid conditions. This deficiency in the battle against DS brings the need to clarify the conditions associated with the development of this highly grave issue. In this, it is imperious to improve the identification

of those factors that have a higher impact on this dysfunction. On the other hand, there are already known factors such as brain and cognitive reserve that appear to diminish the effects and, as a consequence, the gravity of this condition.

With the increasing improvement of technology as an ally, we believe investments in prevention (in addition to the actual treatment) have the capacity to assist in the process of lowering the amount of individuals with DS. This may be achieved by making use of an ecological treatment capable of generalizing cognitive functions (In terms of assessment, the VR, is a good example already in use). However, this apparently doesn't occur in exhaustive computer-training, in which an improvement on a particular test (N-BACK, for instance) does not necessarily relate to a better capacity in working memory in day-to-day life.

Overall, the current researches have been gathering results that demonstrate an optimistic road towards dealing with DS successfully that still needs improvement. Researches applied in this sense must constantly innovate and, through the use of technology, develop more forms of treatment and prevention. In this same sense, there must be a greater amount of early diagnosis of prodromic symptoms so that at the same time the treatment becomes more efficient, the severity of DS diminishes.

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