Executive Functioning

WHERE IS IT CONTROLLED AND HOW DOES IT DEVELOP?

The executive functions are a set of processes that have to do with managing oneself and one's resources in order to achieve a goal. It is an umbrella term for the neurologically-based skills involving mental control and self-regulation.

Executive functioning deficit is often used as a catch-all diagnosis for higher-order communicative-cognitive difficulties that are not clearly understood or diagnosable. Executive functioning (EF), when used to describe poor functioning, is often thrown about rather casually with minimal understanding of the immense impact the deficits can have on a person with said difficulties. Great strides have been made in identification and treatment with more and more practitioners realizing the devastating and often life-altering impact these subtle difficulties have on interpersonal skills, return-to-work potential, social communication and the ability to manage a home. In order to best treat executive dysfunction, we must understand brain anatomy as it relates to EF, definitions and models of EF, developmental acquisition of EF, remediation techniques, and future research directions.

This article and a follow-up article in the next edition will explore all of these concepts.

THE ROLL OF THE EXECUTIVE SYSTEM

The role of the executive system is to handle novel situations outside of the domain of some of our more automatic psychological processes. Norman and Shallice (1992) outlined five types of situations in which routine activation of behavior would not be sufficient for optimal performance, and where executive functions must kick in.

1. Situations that involve planning or decision making
2. Situations that involve error correction or trouble shooting
3. Situations where responses are not well-rehearsed or contain novel sequences of actions
4. Dangerous or technically difficult situations
5. Situations that require overcoming strong habitual response or resisting temptation

The executive functions are often evoked when it is necessary to override responses that might otherwise be automatically elicited by stimuli in the external environment. For example, when being presented with a potentially rewarding stimulus, such as a piece of pie, a person might have the automatic response to take a bite. However, where such a response conflicts with internal plans (having decided not to eat pie due to being on a diet), the executive functions might engage and inhibit the response.

Working memory and executive functioning

There is also a connection between working memory and executive functioning. Working memory is a limited capacity system that temporarily maintains and elaborates information and supports human thought processes (Baddley, 2003). It is often viewed as the cornerstone or pivot point for higher order cognitive processes.

Serino et al. (2006) and Purdy state that in the initial stage of problem solving and goal-directed behavior, working memory is crucial. Working memory provides the storage and workspace for information, whereas executive functions perform operation on the information held in working memory so the information may be used efficiently. During working memory tasks that involve goal-directed behavior, the memory system, either verbal or nonverbal, must be strong in order to allow the executive system to determine the most suitable strategy from a set of alternatives, mentally checked and modified if necessary. Purdy, in the text Cognitive Communication Disorders, summarizes the interplay between working memory and executive functions in Figure 1.
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**WHAT AREAS OF THE BRAIN CONTROL EXECUTIVE FUNCTIONING?**

Executive functions are located primarily in the prefrontal regions of the frontal lobe with multiple neuronal connections to other cortical, subcortical and brainstem regions. Neuroimaging and lesion studies from a variety of neurological diseases and injury models have confirmed the findings. However, it should be noted that prefrontal injury does not directly affect specific cognitive or linguistic processes; rather it affects their regulation and effective use, likely through alteration of the numerous neuronal connections between the prefrontal cortex and other brain regions.

If the distinction between a cognitive process and executive control over the process is not clearly drawn, assessment results may be incorrectly interpreted (e.g., normal scores on memory or language tests interpreted to mean that functional memory and language are intact) and inappropriate treatment prescribed (e.g., process-specific retraining exercises versus functional, contextualized, metacognitive intervention).

The dorsolateral prefrontal cortex (fig. 2) is involved in ‘online’ processing of information such as integrating different dimensions of cognition and behavior. The areas have been found to be linked to verbal and design fluency, ability to maintain and shift set, planning, response inhibition, working recall, organization skills, reasoning, problem solving and abstract thinking.

The anterior cingulate cortex is involved in emotional drives, experience and integration. Associated cognitive functions include inhibition of inappropriate responses, decision making and motivated behaviors. Lesions in this area can lead to low drive states such as apathy, abulia or akinetic mutism and may also result in low drive states for such basic needs as food or drink and possibly decrease interest in social or vocational activities and sex.

The orbitofrontal cortex plays a key role in impulse control, maintenance of set, monitoring ongoing behavior and socially appropriate behaviors. It also has a role in representing the value of reward based on sensory stimuli and evaluating subjective emotional experiences. Lesions can cause disinhibition, impulsivity, aggressive outbursts, sexual promiscuity, and antisocial behavior.
DEFINITION AND MODELS

The executive system is a theorized cognitive system that controls and manages other cognitive processes. To date, there is very little agreement on one method or construct that is the model of how the executive system functions. However, executive functioning involves complex cognitive processes. Elliot (2003) described a definition posited by Funahashi whereby executive functions involve “flexible coordination of sub-processes to achieve a specific goal.” Changes in framework have occurred over time and with gains in neuroimaging, further adaptations will occur. Typical models of executive functioning determine the skills to be either part of a hierarchy or as part of a metacognitive system.

METACOGNITIVE MODELS

The word “metacognitive” generally means “thinking about one’s own thinking.” So, from that perspective, metacognitive systems stress “one’s ability to view, observe, and assess more basic cognitive procedures and includes self-awareness, self-monitoring, and self-control of cognition while performing an activity” (Kennedy & Coelho, 2005). It is a dynamic process that views lower order processes as automatic (outside of executive functions) and does not contribute to the higher order skill. Two models, the Supervisory Attentional System (SAS) and Miller and Cohen’s model are examples of metacognitive processes.

The SAS is centered on the idea that routine or well-established schemas automatically respond to routine situations while executive functions are used when we are faced with novel situations. Miller and Cohen (2001) presented the theory that the prefrontal cortex directs cognitive control and that the “control is implemented by increasing the gain of sensory or motor neurons that are engaged by task or goal directed elements of the external environment.” Their theory imparts that the action of the prefrontal cortex “is to guide the flow or neural activity along pathways that establish the proper mappings between inputs, internal states, and outputs needed to perform a given task.”

Hierarchical models are based on the premise that executive functions receive input from lower level or more basic processes, such as attention and language, as well as higher level metacognitive processes. (Stuss, 1991). Figure 3 (left) provides a summary of predominant hierarchical systems.

FUNCTIONAL DEFINITION OF THE EXECUTIVE SYSTEM

With a variety of models to conceptualize EF, how can we sum up executive functioning in a cohesive understandable format? One way is to utilize a functional/operational definition of the executive system shown in Figure 4 (above).
Genetics and environment have an influence on how one develops higher-order cognitive skills. Gender also plays a role. Despite these influences, some generalizations can be made across the life span about executive functioning development.

Executive functions develop across the life span with the first signs noted in infancy. Research has shown inhibitory control and working memory skills emerging in children as young as 7-12 months. This is seen through means-end development. The child is able to hold one piece of information in mind in order to act on another. The skill is very fragile and highly susceptible to distraction.

By the age of one, children begin to display gains in selective attention with external distraction not as predominate. At the age of two, children become more capable of problem solving with the acquisition of language. They begin to use language to regulate behavior. At two, children are also able to follow verbal rules, requests and directives. They are beginning to keep verbal rules in mind and use them to guide their behavior. Gains in rule and language use continue to grow and impact learning.

By three years of age, the child is no longer impulsively responding to stimuli in a rigid stereotyped means but rather acting deliberately and flexibly in light of a conscious plan.

Between the ages of three and five, children demonstrate significant gain in performance on tasks of inhibition and working memory. They are beginning to reflect on their own actions. Cognitive flexibility, goal-directed behavior and planning gains are noted. They are developing complex sets of rules to guide/regulate their behavior. They begin to ‘think’ about the intention or the act of doing rather than simply responding to the environment.

As children mature and change, they continue to gain in inhibitory control, and attentional capabilities are noted.

During the primary school years and
into early adolescence, the main changes are made in the ability to consider variables and act accordingly. Preschoolers can verbalize their knowledge of what is the right thing to do but often are not able to actually follow through on it. The need for immediate gratification overrides planning and reasoning capabilities. Further, their ability to successfully implement strategies to limit impulsive responses are not yet developed, though emerging.

External supports and modeling provide reinforcement and help internalize strategies. Gains in planning, goal setting/directed behaviors problem solving and cognitive flexibility are continuing and providing the basis for social skills and academic success during pre-adolescence and adolescence.

The role of executive function development is most clearly demonstrated and often most acknowledged during the teenage/adolescent years. This is in part due to high-risk behaviors that are observed during adolescence, such as alcohol/drug use and unprotected sex.

By the age of 15, working memory, inhibitory control and the ability to sustain and appropriately shift attention are close to adult levels and remain relatively stable with some small increases noted into adulthood. Though, the teen is functioning at or near adult levels, their self-monitoring and self-reflective abilities are not fully mature. Further, when placed in highly complex situations or a situation in which one is required to integrate numerous pieces of information to make an informed decision, the teen will show shortcomings. They tend to base decisions on the advantage of a given situation versus the disadvantages.

Decisions and actions are based on the specific moment and do not consider the long-term consequences, rather making decisions based on their view of themselves at the moment and how they will be perceived by outsiders.

Dr. Zelazo (2010) explains the shortcoming as a “competition between the top-down influence of executive function and the bottom-up influence of desires, drives, impulses and habits.”

As the executive system matures, adults are able to use stored knowledge about themselves and draw on their past experience in making decisions.

In adulthood, gains and decline in executive skills are noted. Between the ages of 20-29, executive functioning skills are at their peak. Decisions regarding marriage, career, family and long-term goals are stable, reflective and highly obtainable. Consideration to outside influences are weighed with internal drives to develop the best outcomes.

As the adult ages, executive functions once again change but this time showing a decline. Declines in higher order cognitive skills have been clearly noted in working memory, self-monitoring, and spatial skills. What has been thought of as normal changes in aging may be the result of an aging

### Key Executive Functions

1. **Awareness** — Age-appropriate insight of strengths and weaknesses.
2. **Planning** — Spontaneous use of planning behaviors in novel tasks; anticipate future events; grasp main idea; prioritize, reduce/cluster information, re-arrange material or information.
3. **Goal setting** — Set intermediate and long-term goals appropriate to abilities.
4. **Self-initiation** — Independently initiate new activities; spontaneous in conversation; begins activity without procrastination, seek and search for information, generate ideas, persist, complete all parts of an activity.
5. **Self-monitoring** — Independently assess behaviors/responses and make changes as needed.
6. **Self-inhibiting** — Behavior is appropriate to changing situations; control impulses, think before acting, pace actions; follow or select according to rules or criteria; manage extraneous distractions, irrelevant information or interference; delay responses.
7. **Ability to change set** — Demonstrate appropriate variations in behaviors; independently consider a variety of solutions in problem solving; revise plans, move freely from one step/activity/situation to another; transition between tasks easily.
8. **Strategic behavior** — Create useful strategies for functional use; able to describe these.
9. **Working memory** — Hold information in mind for the purpose of completing a task.
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the prefrontal cortex and demyelination—a deterioration of the myelin sheath surrounding neurons which results in a slowing of impulses that travel along the nerve.

The adage of “use it or lose it” may very well be true in the realm of executive skills. Continued cognitive involvement/stimulation may promote neuronal myelination or, at minimum, slow the course of demyelination contributing to greater quality of life, independence and overall functional skill.

References


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