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The Nature of ADHD: The Executive Functions and Self-Regulation

Russell A. Barkley, Ph.D.
Clinical Professor of Psychiatry
Medical University of South Carolina
Charleston, SC

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Sources:

Email: drbarkley@russellbarkley.org
Website: russellbarkley.org
Disclosure

Retirement Pension: State of Massachusetts (UMASS Medical School)

Speaking Fees Received From (for 2010):
- Puerto Rico Association of Pediatricians (San Juan)
- Canadian Attention Deficit Disorders Resource Alliance (Toronto)
- ADHD Resource Alliance (The Netherlands)
- Region IV School District of Houston, TX
- PACER Center (Minneapolis, MN)
- Berkshire Area Health Education Cooperative (Pittsfield, MA)
- Association of Educational Therapists (Los Angeles, CA)
- Premier Education Solutions (PESI, Eau Claire, WI)
- Texas A & M University
- American Professional Society for ADHD and Related Disorders (APSARD)
- Southern Connecticut State University
- Fitchburg State College
- University of South Carolina Medical School – Pediatrics Dept.
- Springer School – Cincinnati, OH
- Macon County Mental Health Center
- The Lovett School – Atlanta, GA
- Premier Educational Seminars, Inc. (PESI)

Royalties:
- Guilford Publications (books, videos, newsletter)
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- J & K Seminars (videotapes), New England Educational Institute (audiotapes), PESI (CDs)
- ContinuingEdCourses.net (internet CE courses)

Speaker/Consultant/Expert Witness for these Pharmaceutical Companies:
- Eli Lilly, Shire, McNeil, Janssen-Ortho, Janssen-Cilag, Novartis
Does ADHD = EFDD???

(Executive Function Deficit Disorder)
The Neuro-Anatomy and Neuropsychology of ADHD Virtually Guarantee It!
The Prefrontal Cortical Networks Involved in EF Are Also the Networks Implicated in Self-Regulation and in ADHD

- **The frontal-striatal circuit**: Associated with deficits in response suppression, freedom from distraction, working memory, organization, and planning, known as the “cool” or “what” EF network

- **The frontal-cerebellar circuit**: Associated with motor coordination deficits, and problems with the timing and timeliness of behavior, known as the “when” EF network

- **The frontal-limbic circuit**: Associated with symptoms of emotional dyscontrol, motivation deficits, hyperactivity-impulsivity, and proneness to aggression, known as the “hot” or “why” EF network


Executive Brain Networks

- Reality testing and error monitoring
- Top-down guidance of attention and thought
- Inhibition of inappropriate actions
- Emotion regulation
- Direct norepinephrine and dopamine regulation by prefrontal cortex

Areas labeled:
- Striatum
- Hypothalamus
- Amygdala
- Norepinephrine and dopamine producing cells
Executive Functioning:

Nature and Problems

Problems with the EF Construct

- Lacks any consensus definition
  - More than 20 definitions exist
  - Most emphasize self-regulation, goal directed behavior, and problem-solving
- Considered to be a meta-construct serving as an “umbrella” term for a set of more specific components
  - But up to 33 components have been attributed by experts to EF
- Assessment of EF nearly always employs psychometric tests. But tests of EF:
  - Are unreliable and often poorly normed
  - Lack ecological validity
    - do not correlate with EF rating scales or observations
  - Do not predict impairment in major domains of life in which EF is important for effective functioning;
  - EF ratings do predict impairment
The Psychometric Approach to Assessing EF Relies on Testing Cold Cognition

**EF Constructs Typically Assessed by Tests:**

- **Inhibition and Interference Tasks**
  - CPTS, Go/No-Go, Stop Signal, Stroop
- **Working Memory Tasks (Verbal & Nonverbal)**
  - Digit span, Mental Arithmetic, N-Back, Spatial Memory, Sequence Memory, Simon Game
- **Fluency Tasks**
  - F-A-S Test, 5-Points Task, Ideational Fluency
- **Planning and Problem-Solving Tasks**
  - Tower of London, Tower of Hanoi, Wisconsin Card Sorting Task
Deficits of Patients with PFC (EF) Injuries

- **Social Deficits**
  - Impaired social relationships, socially inappropriate behavior
  - Less independent and self-reliant; greater need for assistance and supervision by others
  - Selfish disregard for the future consequences of one’s actions for one’s self and others

- **Poor Self-Restraint**
  - Impulsive – behaviorally, verbally, cognitively, and emotionally
  - Unable to subordinate their immediate selfishness to the interests of others or to their own longer-term welfare

- **Emotion and Drive Regulation Deficits**
  - Impatient, easily frustrated, emotionally dysregulated, prone to hostility and aggression
  - Primary drive states become dominant and uninhibited;
  - Loss of self-motivation
  - Disinhibited sexual conduct

- **Deficits in Ethical-Moral Conduct**
  - Antisocial behavior and, sometimes, even psychopathic features
  - Unable to manage social, familial, and community responsibilities
  - Disregard for social norms and laws

- **Economic Deficits**
  - Difficulties with occupational functioning – poor time management & self-organization
  - Problems managing money (careless spending, credit binges, disregard for their financial obligations and future)
Rating Scales of EF in Daily Life
Reveal 5 Major Inter-Related Factors

- **Self-Restraint (Inhibition)**
  - Cognitive, behavioral, verbal, emotional

- **Self-Management to Time**
  - Consideration of past and future consequences before acting; managing self relative to time and deadlines

- **Self-Organization & Problem-Solving**
  - Innovating, planning possible response options, problem-solving to overcome obstacles to goals, rapid assembly and performance of novel goal-directed behavior

- **Self-Motivation**
  - Substituting positive goal-supporting emotions for negative goal-destructive ones

- **Self-Regulation of Emotion**

Current Paradox

- ADHD is a disorder of brain networks that contribute to EF – so it has to be an EF disorder
- But only 35-50% or fewer ADHD cases are impaired on EF psychometric tests (≥93rd %)
- Yet 86-98% of clinical-referred adults with ADHD are impaired on rating scales of EF in daily life as are 65-75% of ADHD children by adulthood with persistent ADHD.
- EF tests have low or no significant relationships with EF ratings in daily life
  - 0-10% of shared variance between tests & ratings
  - less than 20% for best combination of EF tests
- EF tests and EF ratings are NOT measuring the same construct
Study of clinic-referred adults with ADHD
(Barkley & Murphy, 2010)

Group differences on EF scales

Comparison of groups on percentage impaired

Percent of Group Impaired > 93rd

ADHD-P = Persistent ADHD, ADHD-NP = Nonpersistent ADHD, Control = Community Control Group

Which Method of Assessing EF is the Most Valid?

• EF scales predict up to 45% of variance in global self-rated impairment and 20% in other-rated impairment
• EF tests predict up to 6% in global self-rated impairment and 7% in other-ratings
• Overall, scales predict 2-20% of variance in work history measures averaging 11%
• Overall, tests predict 2-18% of variance in work history measures averaging 6.8%
• EF ratings predict a wider array of occupational problems than do EF tests
• If predicting impairment is an index of validity of measurement, EF scales out-predict EF tests
What’s Wrong with EF Tests?

• Cannot capture EF as it functions to enact and sustain goal-directed behavior across long spans of time
  – Most tests last just 15-30 minutes each
• Do not capture the important social factors that EF evolved to address
  – Reciprocity, cooperation, mutual support
• Do not evaluate emotional self-regulation
• Fail to capture the link between EF and culture (both its creation and adoption)
How to Resolve the Problems?

• Make self-regulation the core of EF
  – A self-directed action
  – Intended to alter subsequent behavior
  – So as to change the probability of a future event or consequence

• Understand that humans use at least 7 different self-directed actions for self-regulation to achieve delayed goals

• Each type of self-directed action can be considered an executive function (or specific component)

• They develop in a step-wise sequence

• These exist to address the problems and opportunities involved in social (group) living

• View EF as a hierarchy of levels (in biology - an extended phenotype) similar to Michon’s model of driving
Building a Theory of EF and ADHD: Linking Inhibition, Self-Control, and the Executive Functions
Building Blocks of A Theory

• Start with a theory of normal
• Inhibition creates the foundation for self-regulation and EF
• Inhibition comprises three related processes:
  1. Inhibiting the prepotent or dominant response (motor, verbal, cognitive, & emotion)
  2. Interrupting ongoing behavior
  3. Interference control: Protecting the EFs from distraction
What is Self-Regulation?

Self-regulation can be defined as:

1. Any action a person directs toward one’s self (a behavior-to-the-self)
2. So as to change their own subsequent behavior from what they otherwise would have done
3. In order to change the likelihood of a future consequence

You cannot direct an action at yourself without inhibiting your responses to the ongoing environment – they are mutually exclusive.
What is EF?

• An executive function can be defined as a major type of action-to-the-self (a type of self-regulation)
• There are 6-7 major types of EFs:
  – Self-Awareness (meta-cognition)
  – Inhibition and interference Control
  – Nonverbal and verbal working memory
  – Emotional - motivational self-regulation
  – Planning and problem-solving
• All can be redefined as actions-to-the-self
• Each likely develops by behavior being turned on the self and then internalized (privatized, inhibited)
• They likely develop in a step-wise hierarchy - Each needs the earlier ones to function well
The EFs Create Four Developmental Transitions in What is Controlling Behavior

- External → Mental (private or internal)
- Others → Self
- Temporal now → Anticipated future
- Immediate → Delayed gratification
  (Decreased Temporal Discounting of Delayed Consequences)
Building an Extended Phenotype of Executive Functioning
Michon’s Model of Driving

**Level I: Basic Cognitive Abilities Required to Drive**
i.e., normal reaction time; visual field perception; motor speed, agility, coordination, and range of motion; visuo-spatial reasoning; hearing; language and reading abilities, etc.

**Level II: Operational Abilities**
i.e., familiarity with and sound management of the vehicle and its components such as steering, braking, acceleration, signaling, mirrors, seat belts, other safety equipment [ex. Driving a car in an empty parking lot]

**Level III: Tactical Abilities**
i.e., abilities required to operate the vehicle on roadways in the presence of and interactions/conflicts with other drivers and their vehicles, such as driving laws, knowledge of safe driving tactics, etc.

**Level IV: Strategic Abilities**
i.e., Purpose or goals for using the car, best routes through traffic to attain the goals, time likely needed to attain each goal, knowledge needed to enact the plan effectively (weather, traffic, construction, known accidents, etc.)
Anterior-posterior (rostral-caudal) hierarchy of cognitive control of behavior

Reliance on Cultural Methods and Products

Social Complexity: Interactions & Networks

Increasingly Abstract, Longer-Term Goals

Increased Valuing of Delayed Outcomes

Extended Time Horizon

Extended Space Horizon

Increased Behavioral Complexity/Hierarchies

Neurological Maturation

Barkley’s Model of EF

**Level I: Instrumental – Self-Directed Abilities**
i.e., self-awareness, executive inhibition and interference control, nonverbal and verbal working memory, planning, problem-solving, self-motivation, emotion regulation

**Level II: Methodical – Self-Reliant Abilities**
Essential for daily adaptive functioning, self-care, and social self-defense
i.e., Self-Organization and Problem-Solving, Self-Management to Time, Self-Restraint, Self-Motivation, Self-Regulation of Emotions

**Level III: Tactical – Reciprocal Abilities**
i.e., Underlies human social exchange, turn taking, reciprocity, promise keeping. Basis of economic behavior (trading); Underlies ethics, social skills and etiquette; Basis for legal contracts

**Level IV: Strategic – Cooperative Abilities**
i.e., Underlies human coordinated group activities in which goals can be attained that are not possible for any individual. Underlies cooperative ventures, division of labor, formation of communities and governments
**Extended Utilitarian Outcomes**

*Time line:* years to decades  

*Nature:* Not an EF level. This level reflects the long-term outcomes of EF for one’s longer-term welfare, such as achieving educational milestones/degrees, getting occupational promotions, resource (property) maintenance/replacement, saving/investing for major purchases and retirement, sustaining marriages, sponsoring children into adulthood, long-term health, estate planning, investment in grand-children, etc.

*Assessment:* *The accrued consequences over time and the archival records of one’s life*
The Extended Phenotype Model of Executive Functioning

- Pre-Executive
- Instrumental – Self-Directed
- Methodical – Self-Reliant
- Tactical -- Reciprocal
- Strategic -- Cooperative
- Extended Utilitarian
Executive Functioning - Defined

EF is the use of self-directed actions (self-regulation) to choose goals, and to select, enact, and sustain actions across time toward those goals, usually in the context of others and often relying on social and cultural means. This is done for the maximization of one’s longer-term welfare as the person defines that to be.

(Barkley, in press)
Understanding the S-R Resource Pool

• Acts of S-R require effort; this diminishes the pool
• Every type of EF activity depletes the pool temporarily
• This adversely affects all subsequent use of EF
• Sustained use of the EF/SR pool so depletes it that any subsequent attempts at EF/SR are at greater risk of failure
• This includes EF/SR used in work, social conduct, moral behavior and other situations where EF/SR would be necessary

Self-Regulatory Strength is a Limited Resource Pool

- S-R Fuel Tank (Willpower)
- Inhibition & Self-Restraint
- Self-Management to Time (NV-WM)
- Self-Organization & Problem-Solving (V-WM)
- Emotional Self-Regulation
- Self-Motivation

The pool increases in capacity with maturation.

Use of EF/SR reduces the pool temporarily.

So Does: Stress, Alcohol, Drug Use, & Illness
Understanding EF Disorders

- PFC Disorders disrupt the 5 levels of EF/SR but especially the tactical and higher levels thereby creating a disorder of self-regulation across time.
- They create “Time Blindness” or a “Temporal Neglect Syndrome” (Myopia to the Future).
- They cause a contraction of the EF hierarchy the extent of which is based on severity of interference with or injury to the PFC.
- They cause a reduction in the 8 developmental capacities (time, space, motivation, behavioral, abstract, social, cultural, etc.).
- They adversely affect the capacity to hierarchically organize nested sets of goal directed behavior across time to anticipate the future and to pursue one’s long-term goals and self-interests (welfare and happiness).
6 Level Hierarchy of EF

- Pre-Executive (non-EF)
- Instrumental – Self-Directed
- Methodical – Self-Reliant
- Tactical - Reciprocal
- Strategic - Cooperative
- Extended Utilitarian

PFC Disorders

Severe PFC Injury
How Does ADHD Fit Into EF?

EF Comprises a Single Domain that Can Be Usefully Subdivided into two Broad Dimensions

**Inhibition:**
- Motor
- Verbal
- Cognitive & Emotional

**Meta-Cognition:**
- Nonverbal WM
- Verbal WM
- Planning/Problem-solving
- Emotional self-regulation

Where does ADHD fit into them?

Hyperactivity-Impulsivity

Inattention
Anterior-posterior (rostral-caudal) hierarchy of cognitive control of behavior

Reliance on Cultural Methods and Products

Social Complexity: Interactions & Networks

Increasingly Abstract, Longer-Term Goals

Increased Valuing of Delayed Outcomes

Extended Time Horizon

Extended Spatial Horizon

Increased Behavioral Complexity/Hierarchies

Neurological Maturation

The Brain as a Knowledge vs. Performance Device

ADHD

Performance

Knowledge
Understanding ADHD

- ADHD disrupts the 5 levels of EF/SR but especially the tactical and higher levels thereby creating a disorder of self-regulation across time.

- ADHD can be considered as “Time Blindness” or a “Temporal Neglect Syndrome” (Myopia to the Future).

- It adversely affects the capacity to hierarchically organize behavior across time to anticipate the future and to pursue one’s long-term goals and self-interests (welfare and happiness).

- It’s not an Attention Deficit but an Intention Deficit (Inattention to mental events & the future).
Understanding ADHD

It’s a Disorder of:

- Performance, not skill
- Doing what you know, not knowing what to do
- The when and where, not the how or what
- Using your past at the “point of performance”

The point of performance is the place and time in your natural settings where you should use what you know (but may not)
ADHD and the Resource Pool

- The extra effort SR requires in someone with ADHD may deplete this pool far more rapidly than in normal people.
- And/or the pool may be smaller in those with ADHD making it more likely to be depleted by efforts at SR.
- Requiring people with ADHD to simply try harder may deplete this pool so much that it leaves them at greater risk for failure in immediately subsequent situations that may require further SR.
- There may be implications here for adverse after-effects from treatments that tax SR/EF during training periods such that following the training period the child or adult is at greater risk for poor self-regulation in subsequent social or academic situations.
Implications for Assessment

• EF tests assess the most rudimentary level. Even then:
  – Their ascertainment window is too brief
  – They ignore the concept of contemplated action across spatial and temporal distances inherent in EF (effects at a distance)
  – They ignore the social functions of EF
  – They completely disregard the use of cultural devices and others as means to ends or goals
  – They cannot evaluate the behavioral complexity needed to person goals in everyday life
  – They ignore the capacity for self-motivation that is essential for goal-directed action
  – They fail to evaluate the important role of emotional self-regulation in human affairs
  – They miss the hierarchical nature of both behavioral structuring and of the rules humans use to guide goal-directed actions (e.g. methods, tactics, strategies, principles)
Implications for Assessment

- Instead of or in addition to EF tests, use:
  - Self- and other-reports of daily functioning
  - Adaptive behavior inventories for the methodical – self-reliant level
    - Vineland, Normative Adaptive Behavior Checklist, etc.
  - Behavior rating scales of EF for the tactical and strategic levels
    - Barkley Deficits in EF Scale; Behavior Rating Inventory of EF
  - Social skills inventories and interviews for social functioning
    - Social Skills Rating System (for children)
  - Ratings of psychosocial impairment for the extended utilitarian level
    - Barkley Functional Impairment Scale; Global Assessment of Functioning
  - Archival records to evaluate the utilitarian level
    - Education, work, financial, driving, military, criminal, etc.
Implications for Treatment

• Teaching skills is inadequate
• The key is to design prosthetic environments around the individual to compensate for their EF deficits
• Therefore, effective treatments are always those at the “point-of-performance”
• The EF deficits are neuro-genetic in origin
• Therefore, medications may be essential for most (but not all) cases – meds are neuro-genetic therapies
• But some evidence suggests some EFs may also be partly responsive to direct training
• While ADHD creates a diminished capacity: Does this excuse accountability?
  – (No! The problem is with time and timing, not with consequences)
More Treatment Implications

- Behavioral treatment is essential for restructuring natural settings to assist the EFs
  - They provide artificial prosthetic cues to substitute for the working memory deficits (signs, lists, cards, charts, posters)
  - They provide artificial prosthetic consequences in the large time gaps between consequences (accountability) (i.e., tokens, points, etc.)
  - But their effects do not generalize or endure after removal because they primarily address the motivational deficits in ADHD
- The compassion and willingness of others to make accommodations are vital to success
- A chronic disability perspective is most useful
How can we compensate for EF deficits? By reverse engineering the EF system

- Externalize important information at key points of performance
- Externalize time and time periods related to tasks and important deadlines
- Break up lengthy tasks or ones spanning long periods of time into many small steps
- Externalize sources of motivation
- Externalize mental problem-solving
- Replenish the SR Resource Pool (Willpower)
- Practice incorporating the 5 strategies for emotional regulation in daily life activities
Replenishing the EF/SR Resource Pool

S-R Fuel Tank (Willpower)

- Greater Rewards and Positive Emotions
- Statements of Self-Efficacy and Encouragement
- 10 minute breaks between EF/SR tasks
- 3+ minutes of relaxation or meditation
- Visualizing and talking about future rewards before and during SR demanding tasks
- Routine physical exercise; Also Glucose ingestion

Regular limited practice using EF/SR and the Willpower Pool can increase later pool capacity. However, the capacity may eventually diminish once practice is terminated.

Conclusions

• The EF/SR system is multi-leveled and arranged in a hierarchy over maturation

• ADHD disrupts behavioral inhibition and the internalization of the instrumental self-directed EFs producing a cascading of deficits into higher levels of EF

• By disrupting EF/SR, ADHD affects:
  – Self-restrain or inhibit behavior, thoughts, words, emotions
  – Self-manage to time; anticipate and prepare for the future
  – Self-organize and problem solve across time
  – Self-motivate across time
  – Self-regulate emotions across time
Conclusions

• Behavior in people with ADHD cannot be hierarchically organized and sustained in support of longer term goals and welfare

• This results in a serious and pervasive disorder of self-regulation across time and settings and impaired social functioning (reciprocity, cooperation, and mutualism)

• Preventing them from dealing effectively with the probable future and pursuing one’s long-term goals and welfare

• Thereby requiring the design of prosthetic environments that compensate for EF/SR deficits while using neuro-genetic medicines to temporarily improve or normalize the instrumental self-directed EFs