Executive functions: Functional neuroanatomy and clinical applications

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Disclosures

• Jerry Hoepner has the following relevant financial relationships in the products or services described, reviewed, evaluated or compared in this presentation.
  • University of Wisconsin – Eau Claire: salary
  • MSHA: honorarium for this seminar

• Jerry Hoepner has no relevant non-financial relationships to disclose
Learner Outcomes

• To identify anatomical correlates of executive function processes in the brain.
• The consequences of damage to the pre frontal cortex, anterior basal ganglia, and related structures.
• The significance of the principle of the paradox of assessing and intervening for executive dysfunction in clinical contexts.
Neurology 101 – Some basic truths & imperatives

• Anterior = motor, posterior = sensory
• Gray matter processes, white matter transmits
• The brain develops in the form of a C – critical to development, aging, and trauma
• Nothing happens in isolation
• Brains are like maps, but they are also like snowflakes
Cortex develops in c-shape... as do lateral ventricles, corpus callosum, basal ganglia, and other cerebral structures
Developmental, aging, & trauma issues

Blumenfeld, 2002
Pathophysiology of TBI

Bigler, 2004; Johnson, 2000
Brain Gardening 101

• Even if you are not a gardener, per se...
• I’ll bet you know something about pruning
• Why do gardeners prune? What is the result?
Brain Pruning?

- Selective trimming
- Efficiency
- Thinning
Brain Pruning?

• Note the thinning of cortex with normal aging 😊
Medial view
Vascular Supply

(A)

(B)

Key
- Anterior cerebral artery
- Middle cerebral artery
- Posterior cerebral artery

(C)

Blumenfeld, 2002
MCA perforating branches: Lenticulostriate arteries

Figure 10.7
Blood Supply of Subcortical Structures

Figure 10.8

(A) Blood vessels supplying the basal ganglia and thalamus

Putamen
Penetrating branches of anterior cerebral artery (e.g., recurrent artery of Heubner)
Lenticonulostriate arteries
Anterior cerebral artery
Internal carotid artery
Middle cerebral artery
Anterior choroidal artery
Caudate nucleus
Thalamus
Globus pallidus
Posterior choroidal artery
Thalamogeniculate arteries
Thalamoperforator arteries
Basilar artery
Posterior cerebral artery

(B) Blood supply to the internal capsule and globus pallidus

Internal capsule (genu)
Corona radiata
Internal capsule (anterior limb)
Optic radiation
Globus pallidus
Anterior cerebral artery
Middle cerebral artery
Anterior choroidal artery
Posterior cerebral artery

Blumenfeld, 2002
Thalamus – well connected
Basal Ganglia

Nolte Figure 19-5

Nolte, 2002
Basal Ganglia

Figure 16.1

(A) Putamen
Body of caudate

Head of caudate
Cellular bridges
Lateral ventricle

(B) Putamen
Body of caudate

Head of caudate

Nucleus accumbens

Globus pallidus, external segment

Globus pallidus, internal segment

Amygdala
Tail of caudate

Amygdala
Tail of caudate

Blumenfeld, 2002
Cortex is organized in layers and columns

Figure 2.14

Layer III cortical-cortical connections
Layer IV thalamo-cortical connections

Blumenfeld, 2002
RAS & Attention Systems

(A)

Basal forebrain and hypothalamus
Thalamus
Pontomesencephalic reticular formation

Rostral recticular formation
Caudal recticular formation

Filey, 2002; Blumenfeld, 2000
RAS continued...
Memory Systems

Declarative (explicit)
- Facts
- Events

Nondeclarative (implicit)
- Skills and habits
- Priming
- Simple classical conditioning
- Nonassociative learning

Medial Temporal Lobe:
- Hippocampus
- Amygdala
- Hypothalamus
- Piriform cortex
- Cingulate G.

Cerebellum
- Basal Ganglia
- Thalamus
- Pons
- Medulla

Blumenfeld, 2002

• H – Homeostasis (hypothalamus et al.)
• O – Olfaction (olfactory cortex, entorhinal, pyriform, et al.)
• M – Memory (hippocampus, amygdala, et al.)
• E – Emotions (amygdala et al.)
Limbic cortex

Blumenfeld, 2002
Production System Model

• Computational model

• The “if, then” model

• Based on pattern matching & conflict resolution

• Doesn’t account for emotions or environment

Working memory and executive functioning are interdependent

Kimberg & Farrah, 1993; Kimberg, D’Esposito, & Farrah, 1997; Cooper & Shallice, 2000
The computational schema

Fig. 2. Schematic organization in the coffee preparation domain. Sectors are indicated by static type and goals by bold type.
Mesulaum’s Default Model

- To make a decision about a novel event we must inhibit our default/knee jerk response

- Default response doesn’t initiate working memory or problem solving
Domain Specificity vs. Generality

• Domain-specific mechanisms are specialized to handle specific repetitive problems with consistent solutions.

• “Domain-general mechanisms will always be weaker than domain-specific mechanisms for dealing with recurrent adaptive problems.”

• Domain-general mechanisms are designed to solve novel problems.
Guess what?

- Domain-general tasks place high demands on working memory

Horn & Hoffer, 1992
Inhibition-Default

Novel
• Engage working memory
• Inhibit tendency to remain in routine, automatic mode

Routine
• Follow the script
• Auto pilot
Damasio’s Somatic Marker Model

• Emotional decision making

• Fed by standards of moral and socially accepted behavior

• Sensitivity to consequence (both reward and punishment)
What are the consequences of executive dysfunction?

In conversations/interactions:

• Problems with code switching (front desk vs. back room language)
• Problems with presupposition and theory of mind
• Problems with social niceities “the veritable icing on the cake”
• Don’t give back to their partners
• Harder to filter and inhibit responses, regardless of being aware of the consequences or “right thing to do”
• Interruptions, failure to listen to their partners, perseverations, egocentrism, and on and on

Galski, Tompkins, & Johnston, 1998; McDonald, 1993; Milton & Wertz, 1986; Cools & Manders, 1998; Coelho, Youse, & Le, 2002
What is the impact of these issues?

• Persons with TBI don’t socially reinforce partners – one of the biggest factors in relationship breakdown!
• Increased conversational burden
• Fewer opportunities to share personal interests
• Less time to make social connections
• More than half (56%) of partner relationships established prior to TBI end post-TBI

Bond & Godfrey, 1997; Coelho, Youse, & Le, 2002; Liss & Willer, 1990; Kreuter, Sullivan, Dahlloff, & Siosteen, 1998
One night at my TBI group...
Why cognitive rehabilitation through metacognitive training rather than social skills training?

• Impairments in social skills are a symptom, not the source of the problem

• People with TBIs have impaired social skills due to impaired working memory and executive functions

• You can train social skills for a context but that training is unlikely to transfer to other contexts (unless, in some cases the partner who is facilitating follows)

Dahlberg et al., 2007; McDonald, Tate, Togher, Bornhofen, Long, Bertler, & Bowen, 2008
Burrachos example

• How do we get to the precipice?

• It may be closer than you think...

• Consider what factors move you towards the threshold...
What is working memory?
So much disagreement, so little time...
Working memory is...
[In very simple terms]

Short-term memory + Mental workspace = Working Memory
Baddeley & Hitch ('74, '86, '92)

Working Memory Model (Baddeley and Hitch, 1974)

Working Memory has replaced STM

Input → Sensory memory → Attention → Central Executive

Visuo-spatial scratch pad

Central Executive

Long-Term Memory

Phonological Loop

Articulatory control

Phonological store
Just & Carpenter (1992)

- Limited capacity
- Activation matters (capacity is dependent on attention)
- Resource reallocation
- Over doing it leads to across-the-board budget cuts (slows and deteriorates processing)
- Simultaneous activation in those with big budgets
Hasher & Zachs (1988)

- Limited capacity
- Sensitive to interference
- Better working memory is dependent on better inhibition and filtering!
And reality lies somewhere in between...

- The dorsolateral and orbital medial PFC are critical in executive control and inhibition for working memory
- No working memory functions are isolated
What happens when working memory becomes overloaded?

• Mind racing
• Frustration
• Anger
• Inefficiency
• Unproductive
• Spinning your wheels
Contributors to overload...

Factors related to WHO-ICF

Hoepner, Buhr, Johnson, & Sather, in prep
Bart
Emotions...

• What happens to you when you get emotional?
• Have you ever had a discussion about an emotionally charged topic?
Hot and Cool EFs

• **Cool EFs**
  • Abstraction
  • Processed in dorsolateral PFC

• **Hot EFs**
  • Emotional/affective
  • Processed in orbitalfrontal/ventromedial PFC

Baron-Cohen et al., 1999; Drevets & Raichle, 1998; Tranel et al., 2007
Addressing the paradox of assessing EF with standardized measures...
Megan
Jennifer
Bob
Where to begin? Problems with hypotheticals.

Case of the professor: Richard is a 56 year old male who sustained a severe head injury after falling from his roof while removing Christmas lights. Landing on the frozen concrete of his driveway, he sustained skull fractures, a large subdural hematoma in the right frontal region, and smaller hemorrhages. He laid in his driveway for about 2 hours before family returned home to find him lying just in front of his vehicle. After 2 months of hospitalization/rehab, he returned home.

Richard was a university professor at the time of his injury. He was characterized by friends and family as a brilliant conversationalist, albeit somewhat eccentric. His initial return home was coupled with daily outpatient programming (3-4 hours), which kept him busy and took some pressure off of his wife and children. When he returned home, he was exhausted and aside from meals either napped or rested in his chair. As per usual, he always had a book in his hand but now, he only read for a few minutes before dozing off.

After a couple of months of outpatient day programming, Richard was ‘doing well’ and thinking about returning to work at the start of the next semester. A gifted professor, his colleagues were eager to make this work. They arranged a lighter load and some supports.
Richard (cont.)

To prepare for his return to work, Richard participated in some further testing and his SLP met with a few of his colleagues.

How do you think he did on neuropsychological testing?

How about language and cognitive measures?
Then what can we do?
References