Executive functions: Functional neuroanatomy and clinical applications

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Michigan Speech-Language-Hearing Association

2016 Convention

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

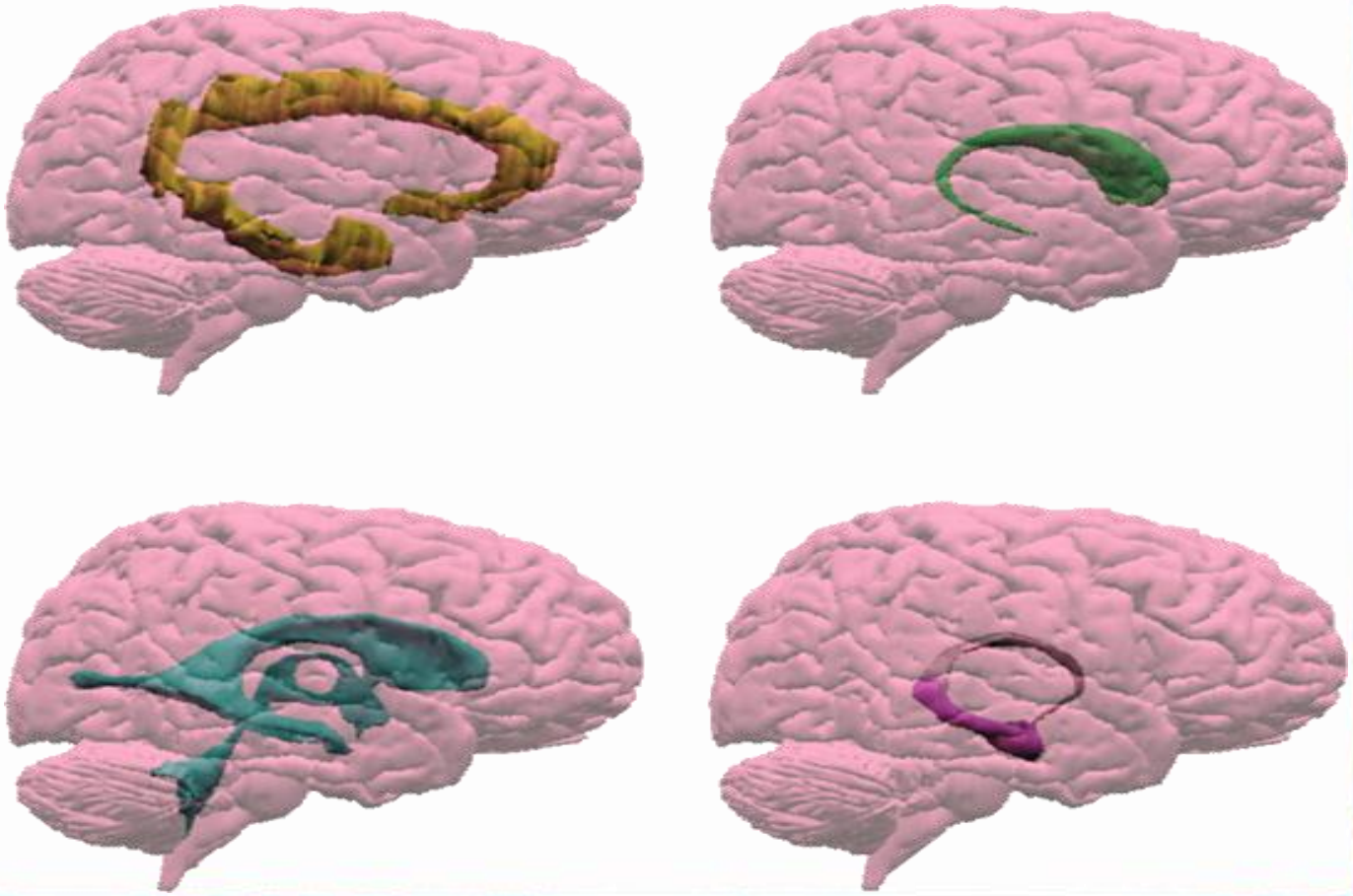
- To identify anatomical correlates of executive function processes in the brain.
- The consequences of damage to the pre frontal cortex, anterior basal ganglia, and related structures.
- The significance of the principle of the paradox of assessing and intervening for executive dysfunction in clinical 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

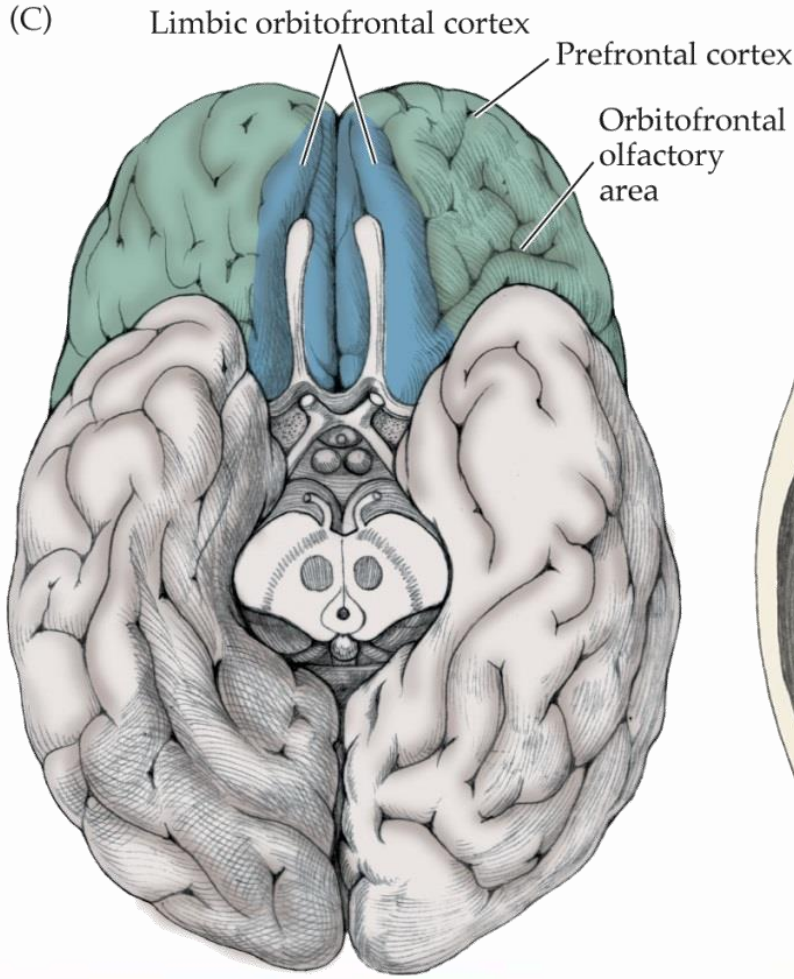
NEUROLOGY
101

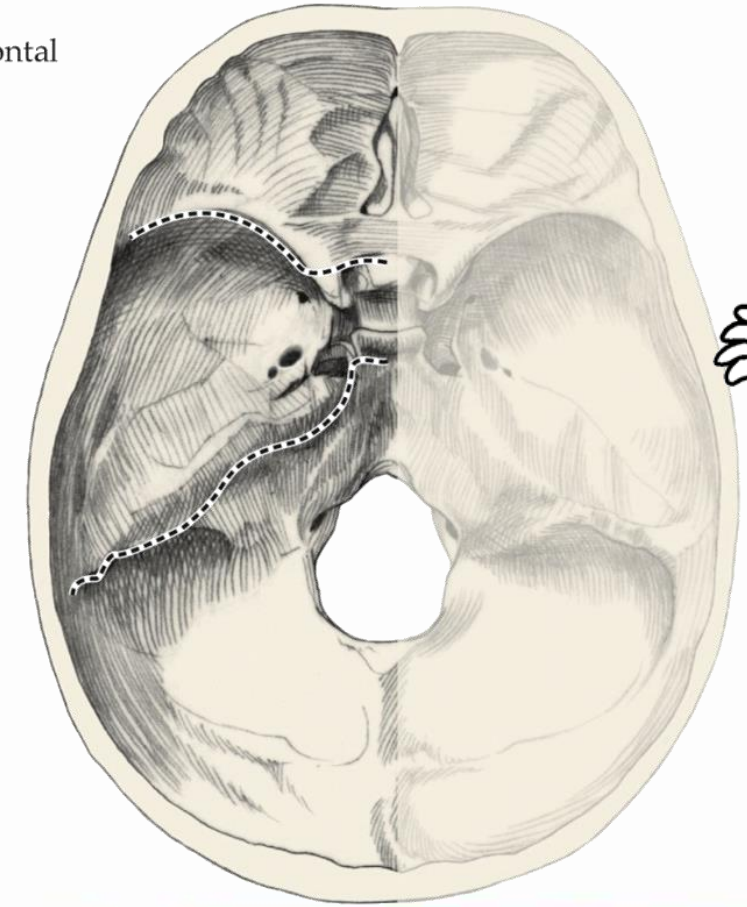
Cortex develops in c-shape…as do lateral ventricles, corpus callosum, basal ganglia, and other cerebral structures



Nolte, 2002

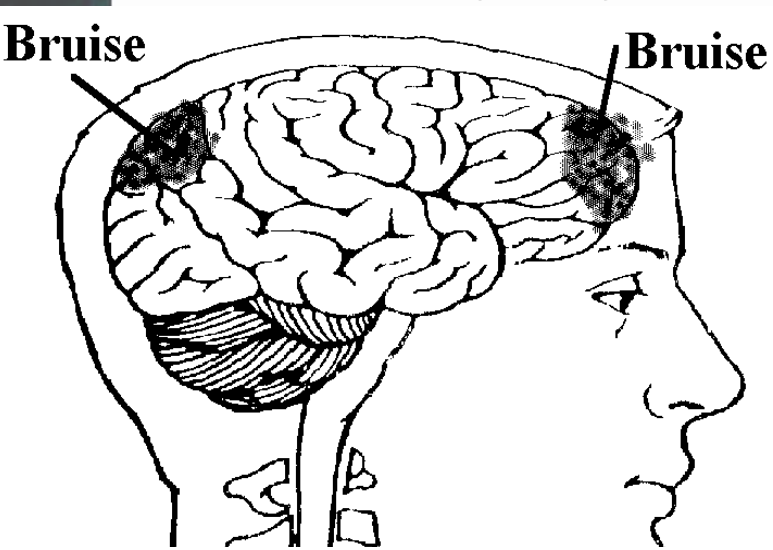
Developmental, aging, & trauma issues

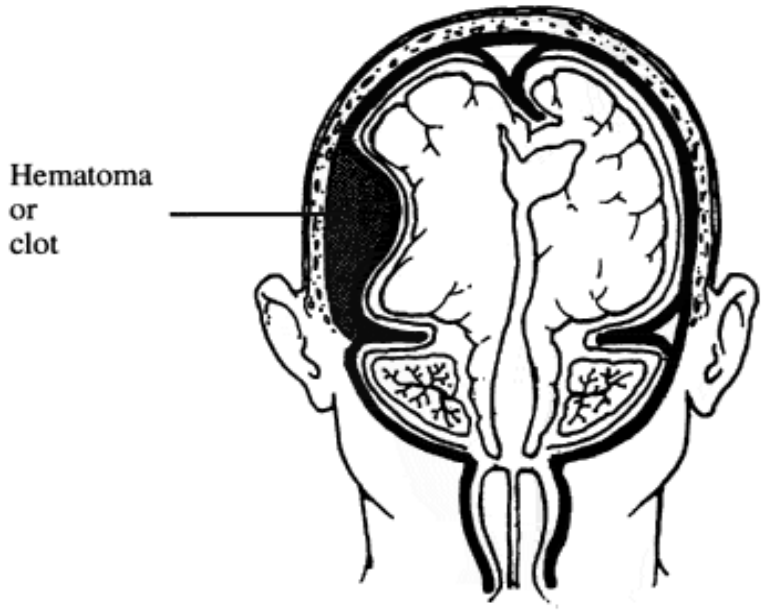


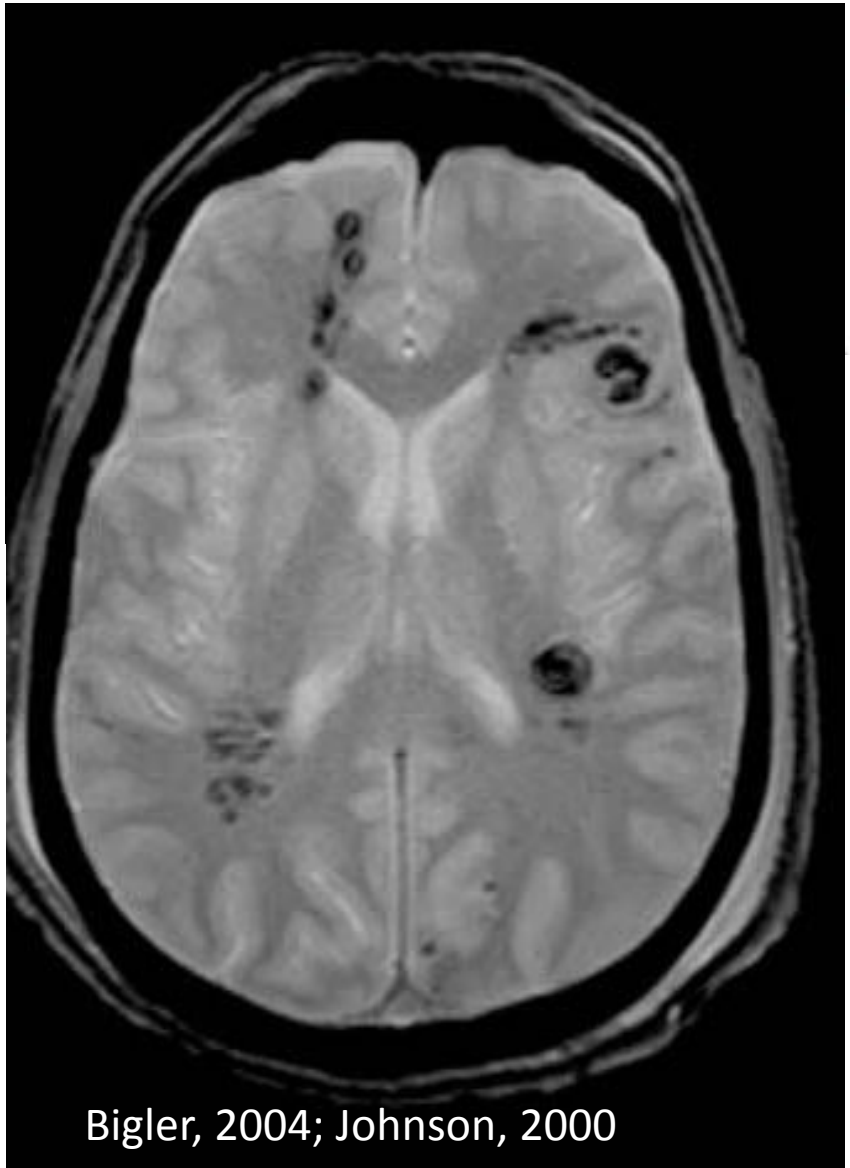


Blumenfeld, 2002

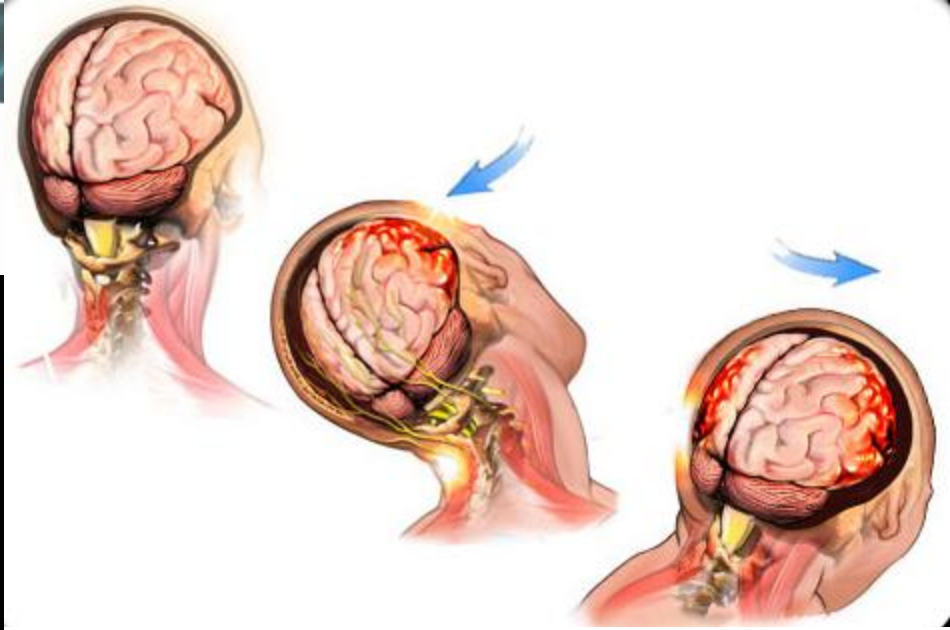
Pathophysiology of TBI

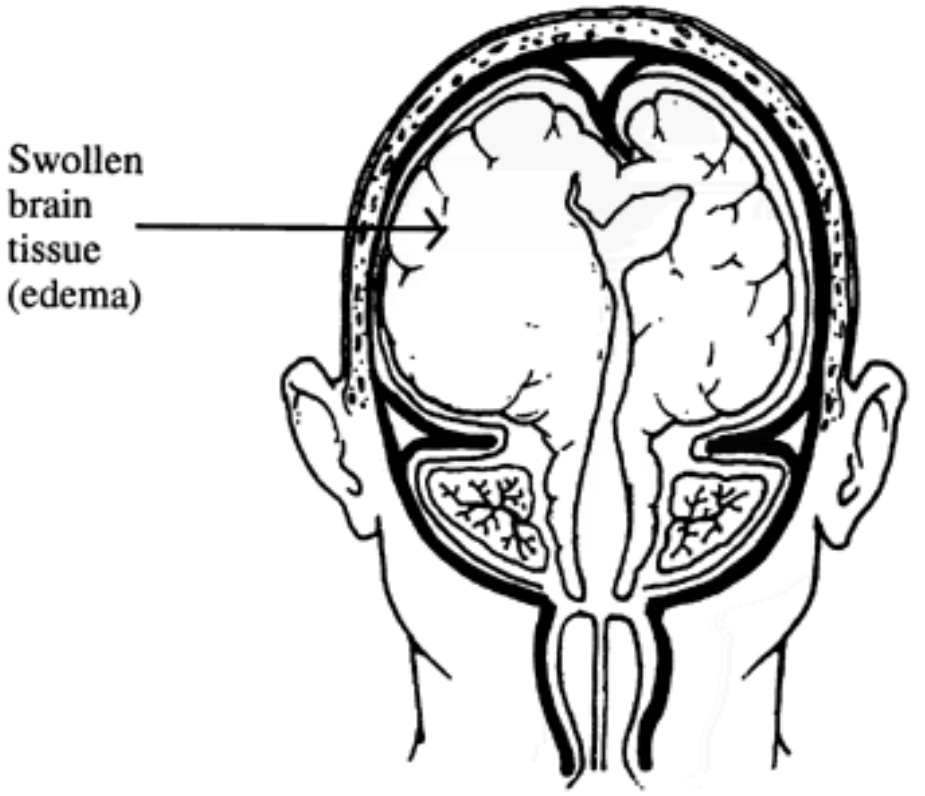






Bigler, 2004; Johnson, 2000



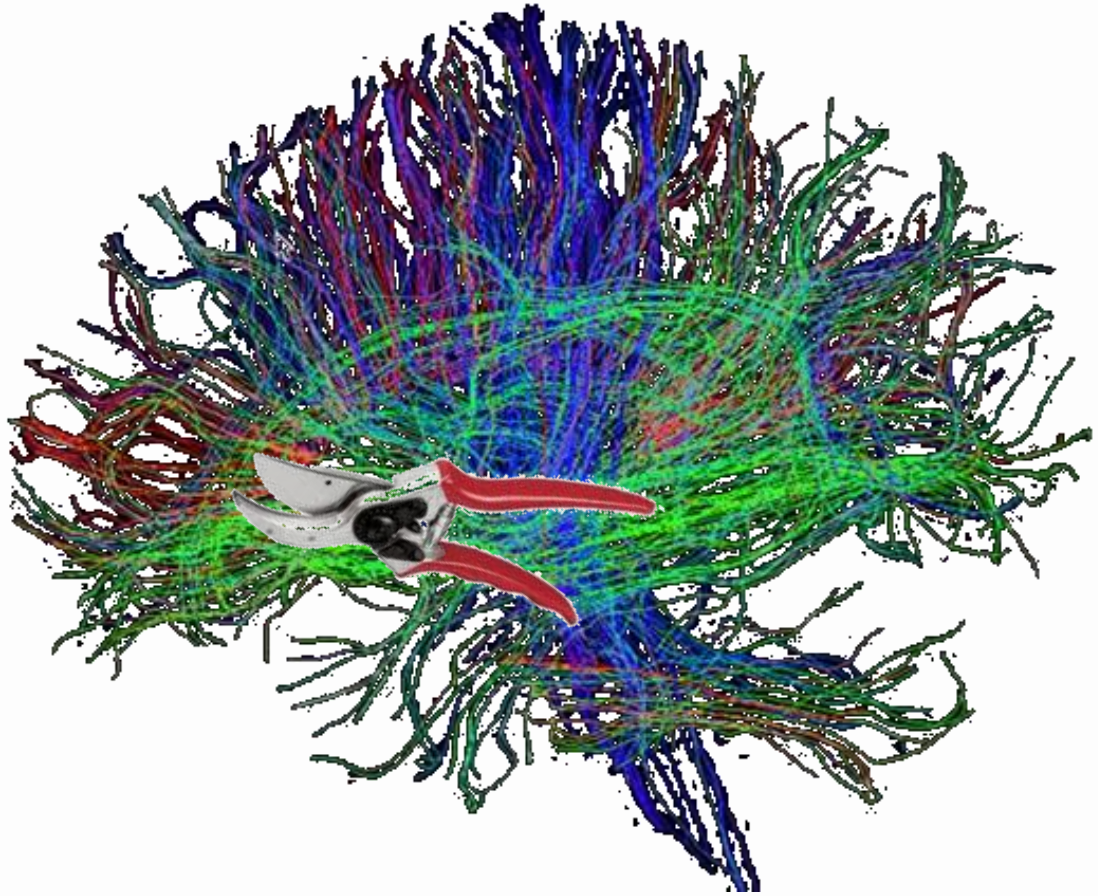


Brain Gardening 101

- 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?

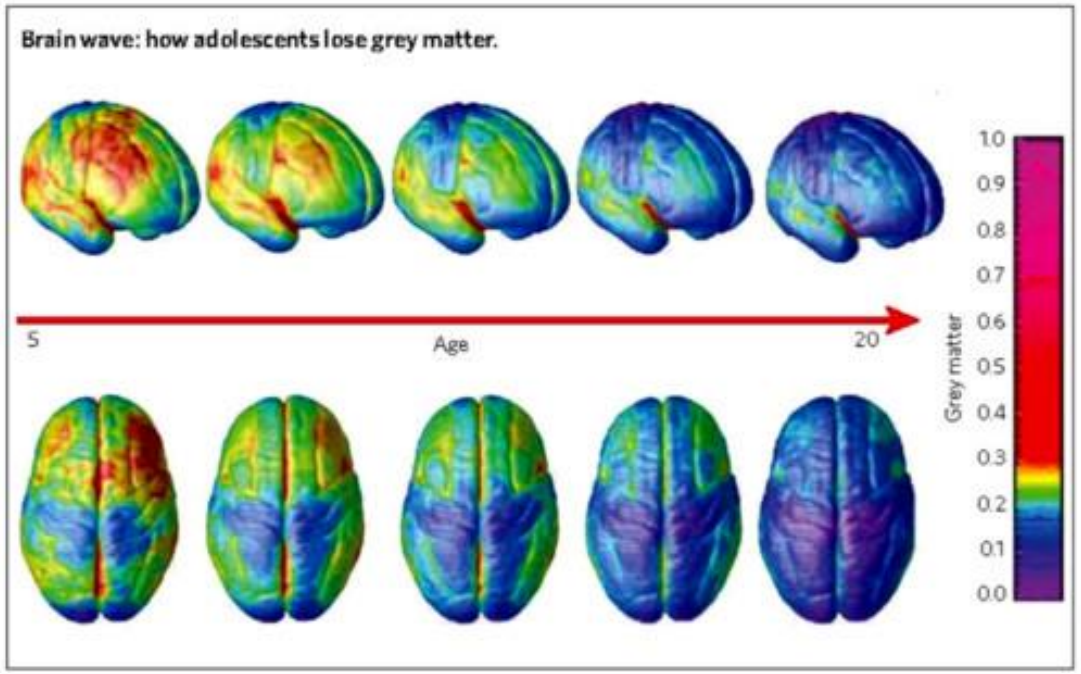
Brain Pruning?

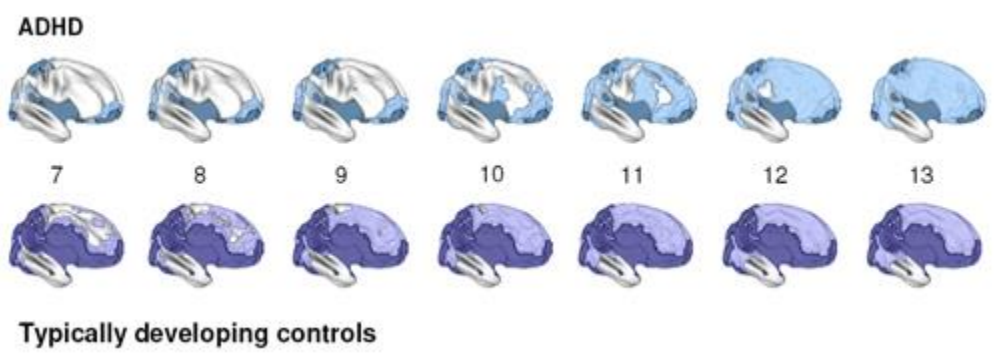
- Selective trimming
- Efficiency
- Thinning

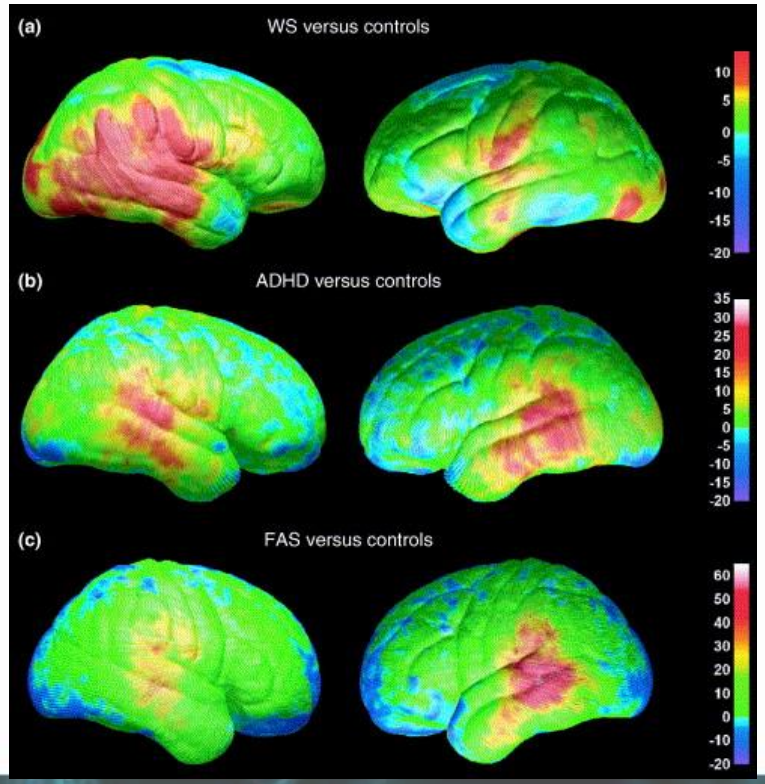


Brain Pruning?

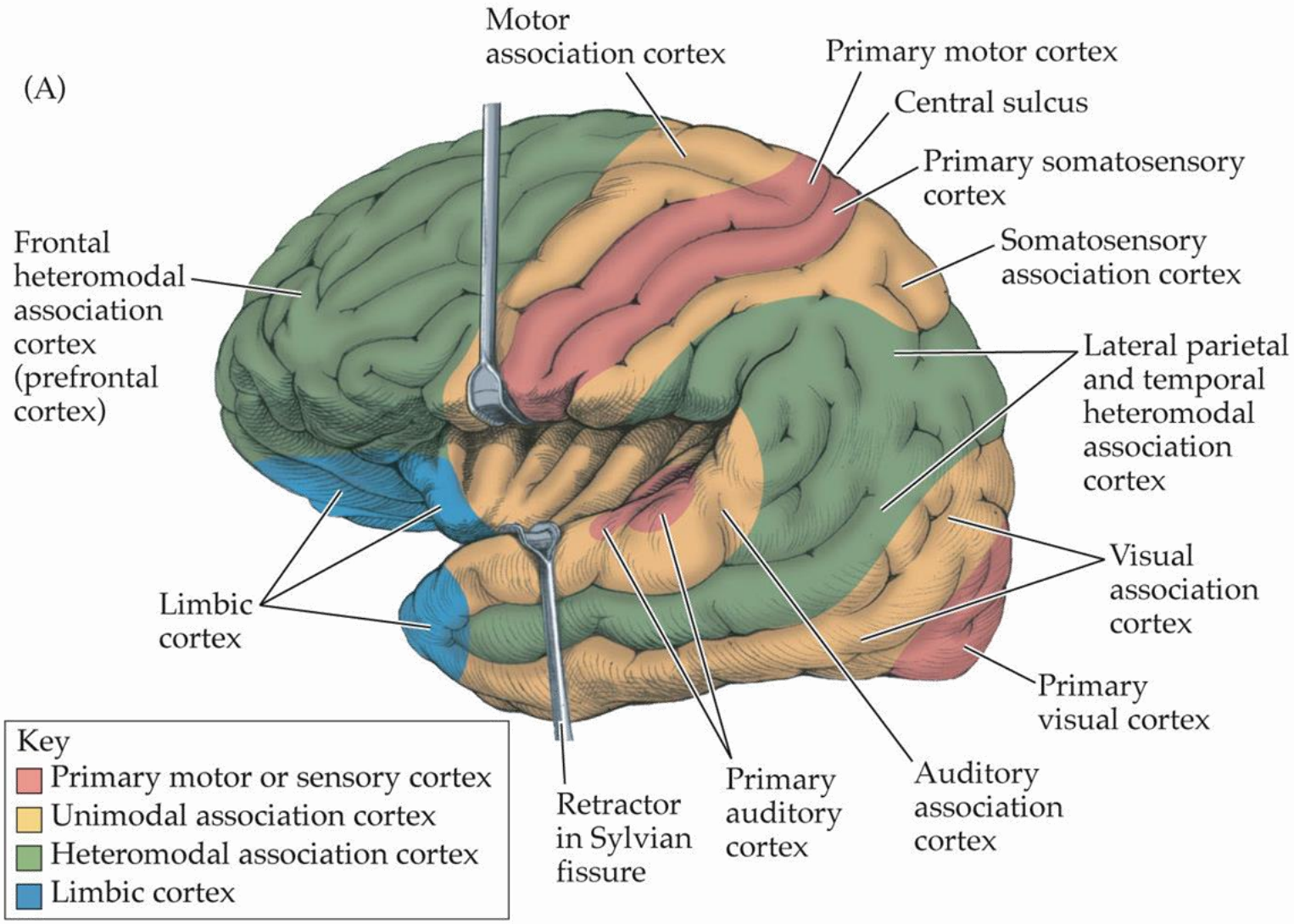
- Note the thinning of cortex with normal aging ☺





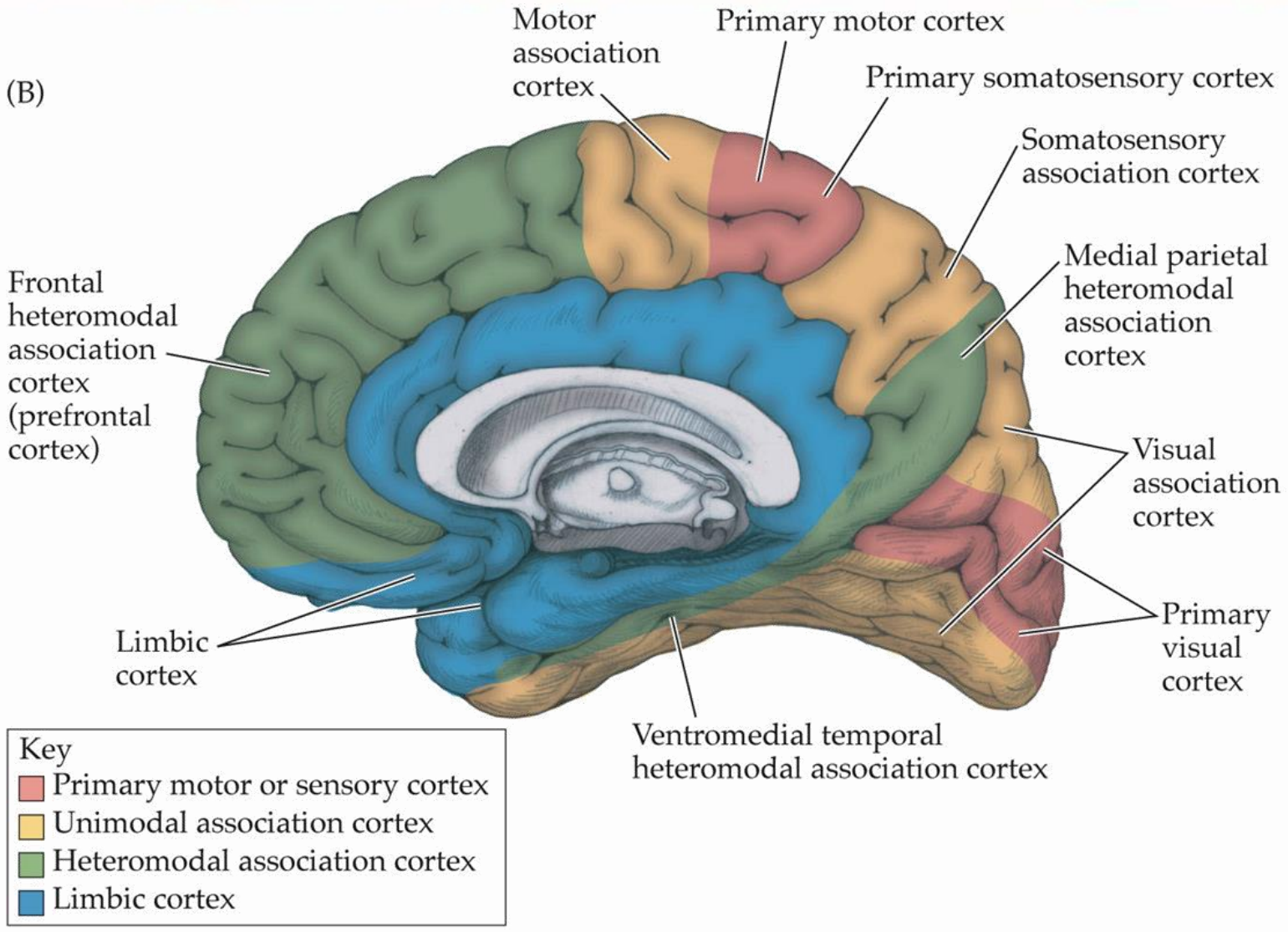


Lateral view



Blumenfeld, 2002

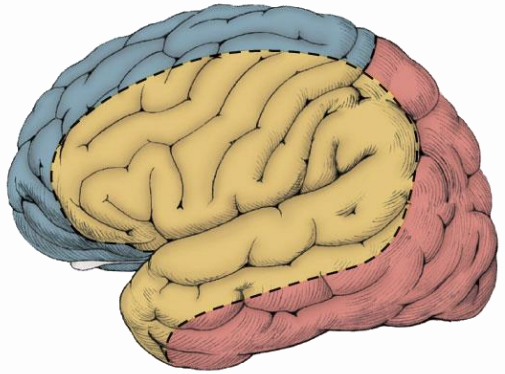
Medial view



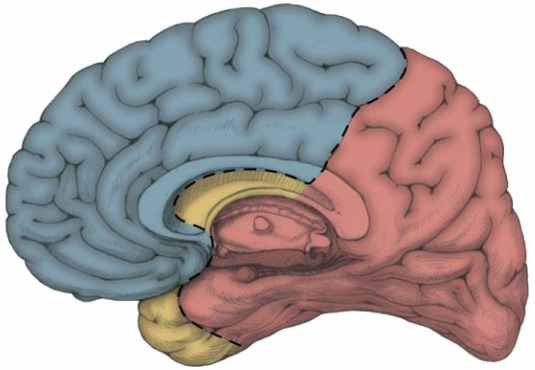
Blumenfeld, 2002

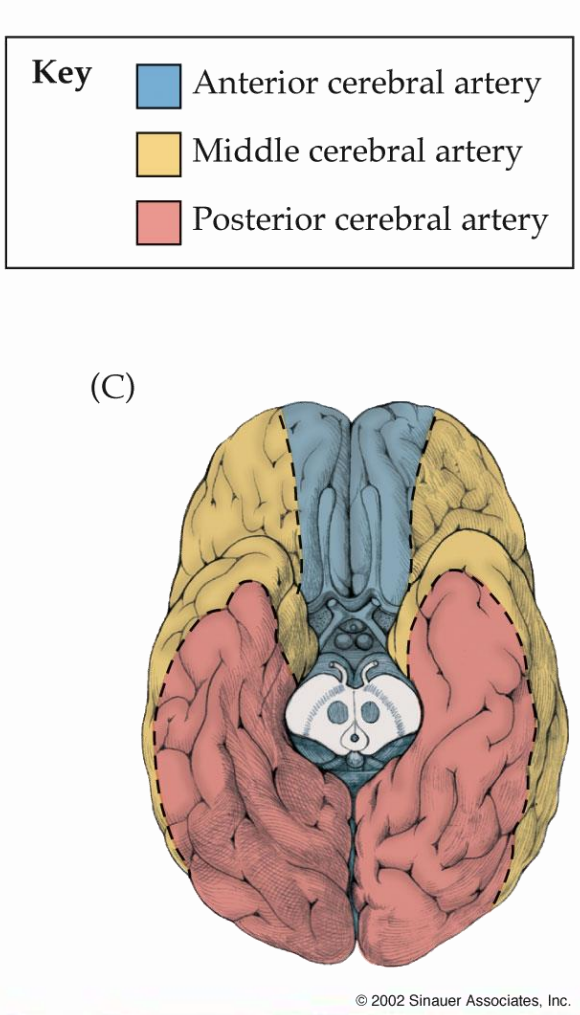
Vascular Supply

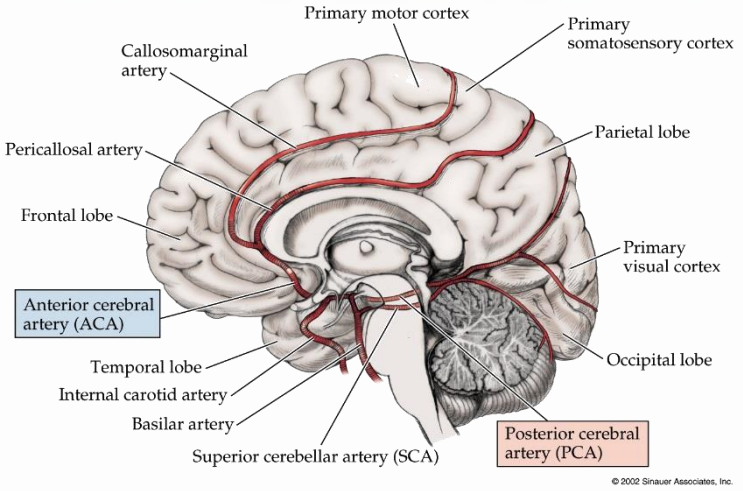
(A)

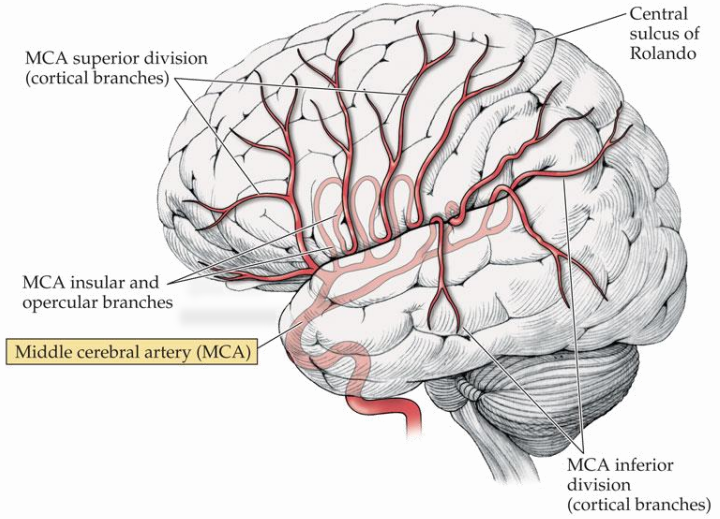


(B)





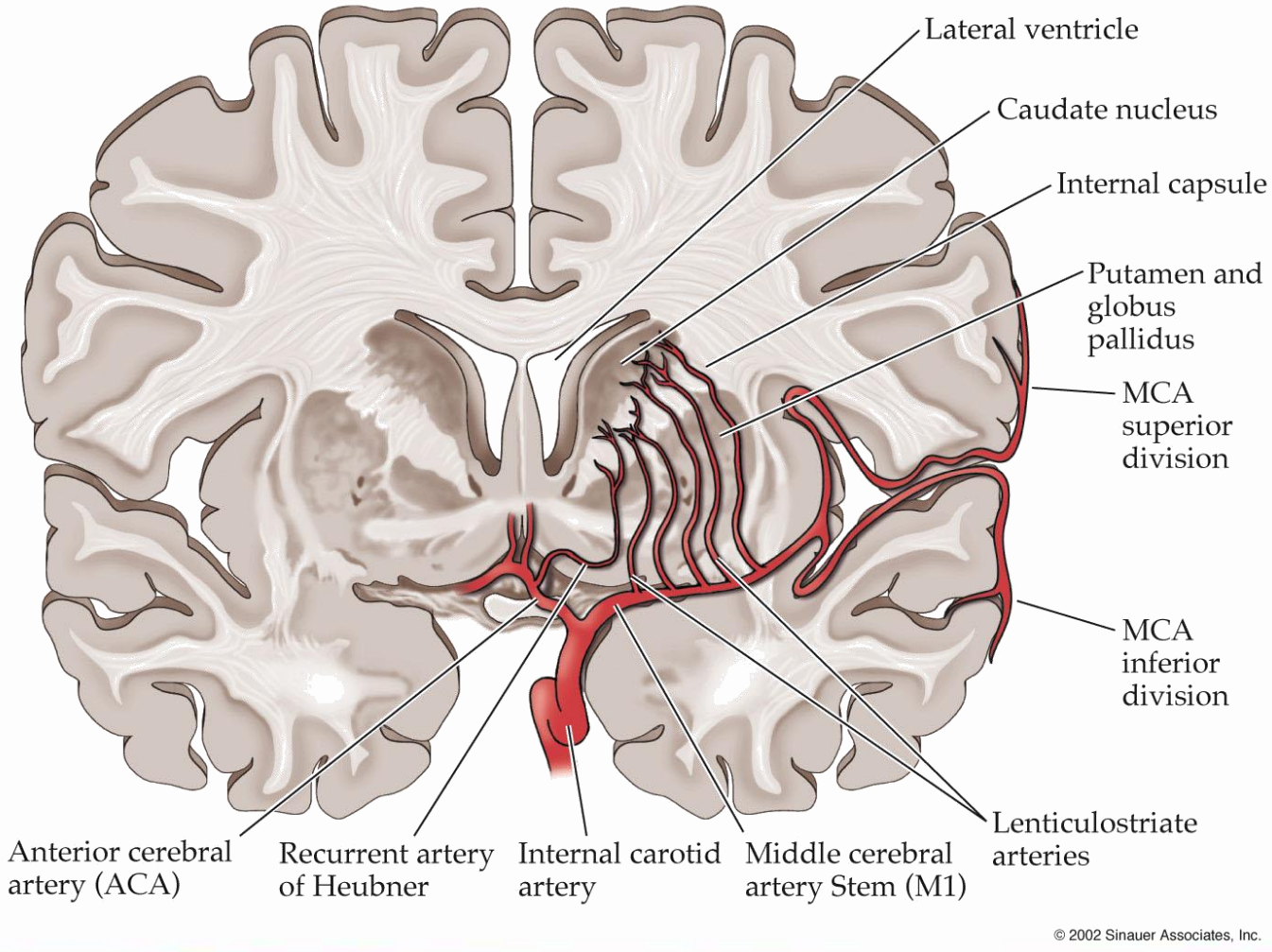




Blumenfeld, 2002

MCA perforating branches: Lenticulostriate arteries

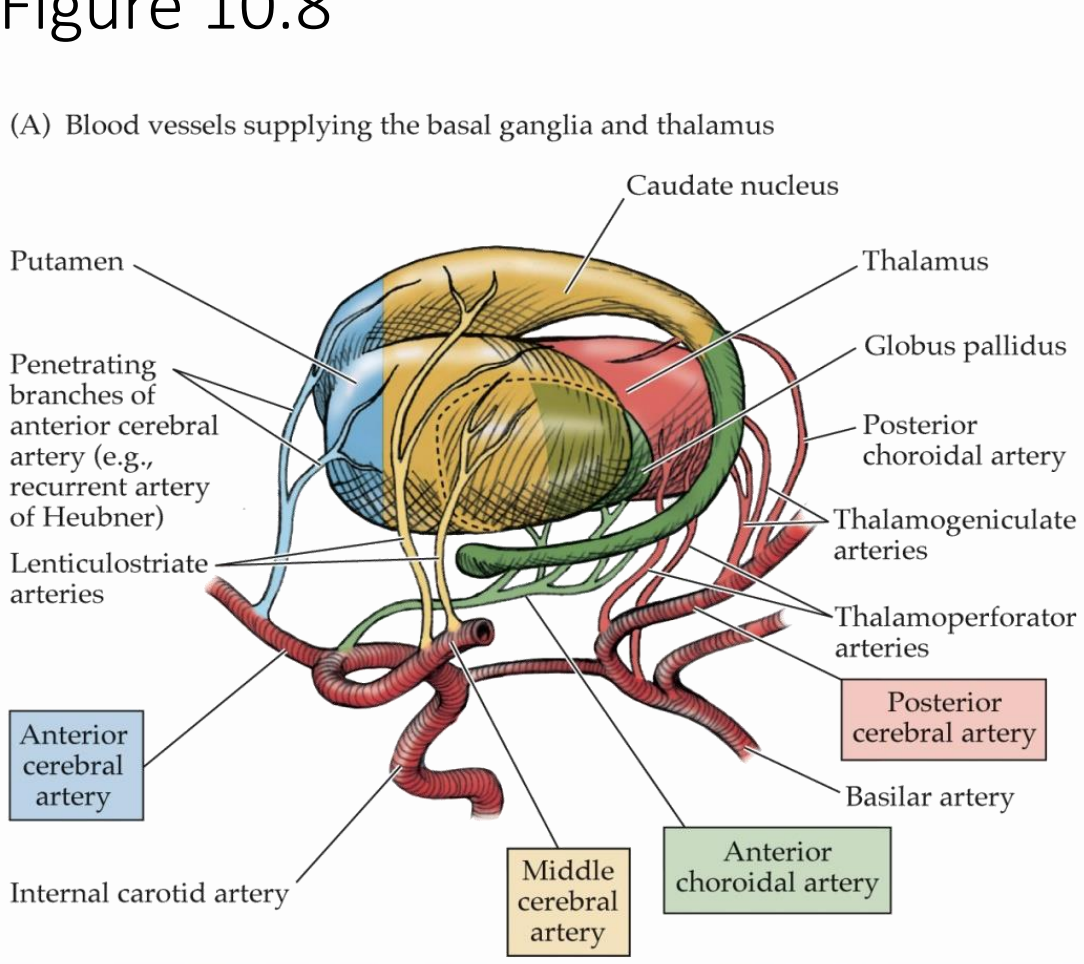
Figure 10.7

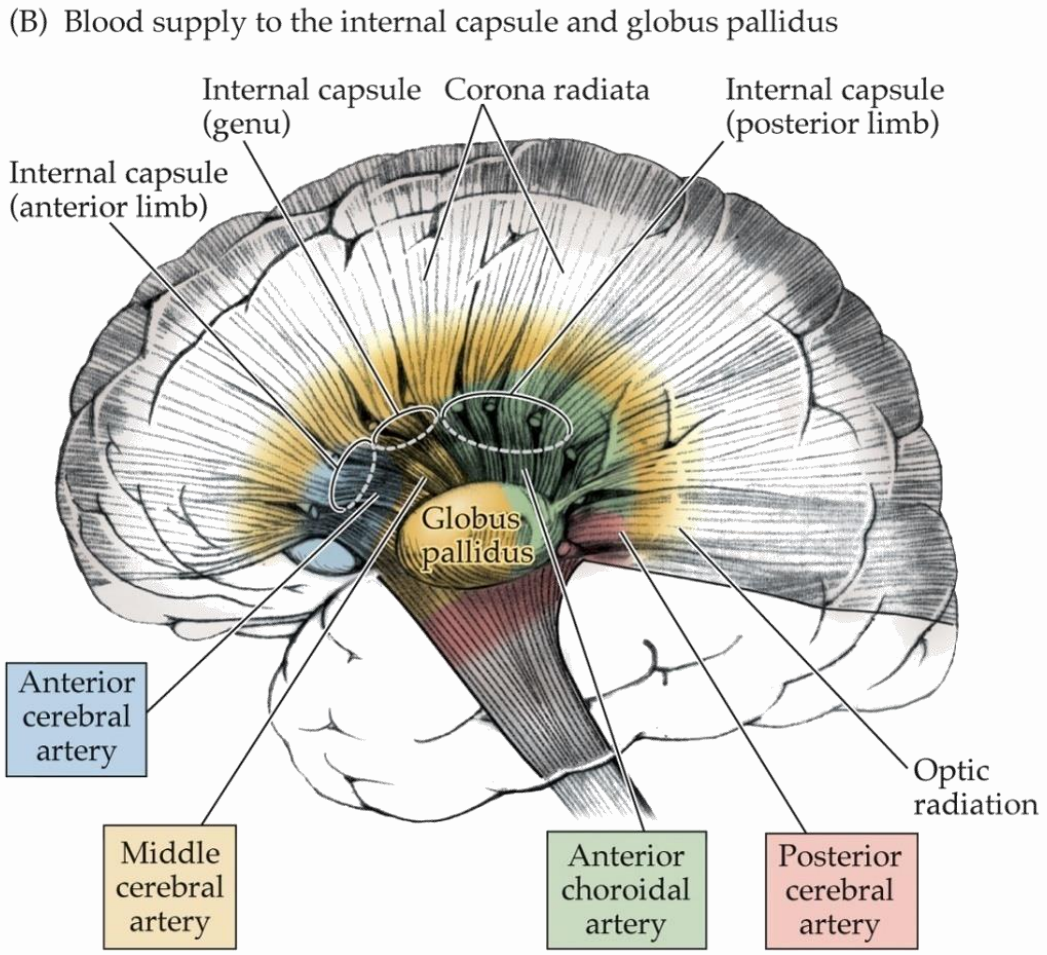


Blumenfeld, 2002

Blood Supply of Subcortical Structures

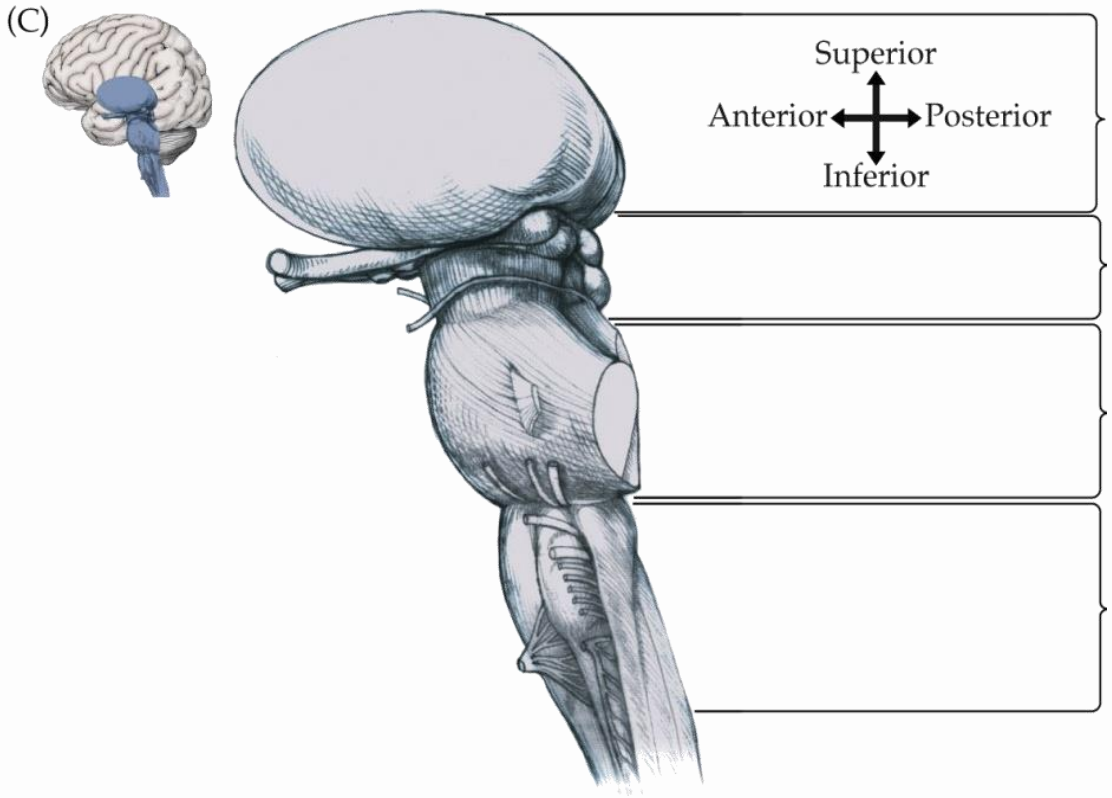
Figure 10.8

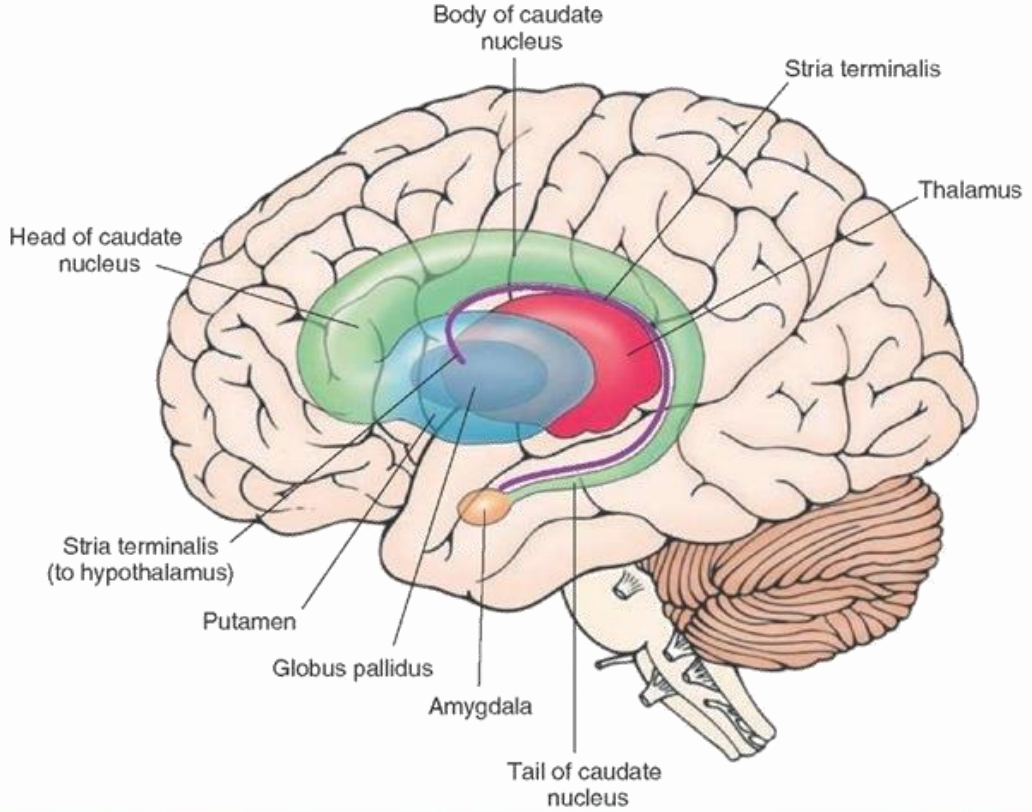




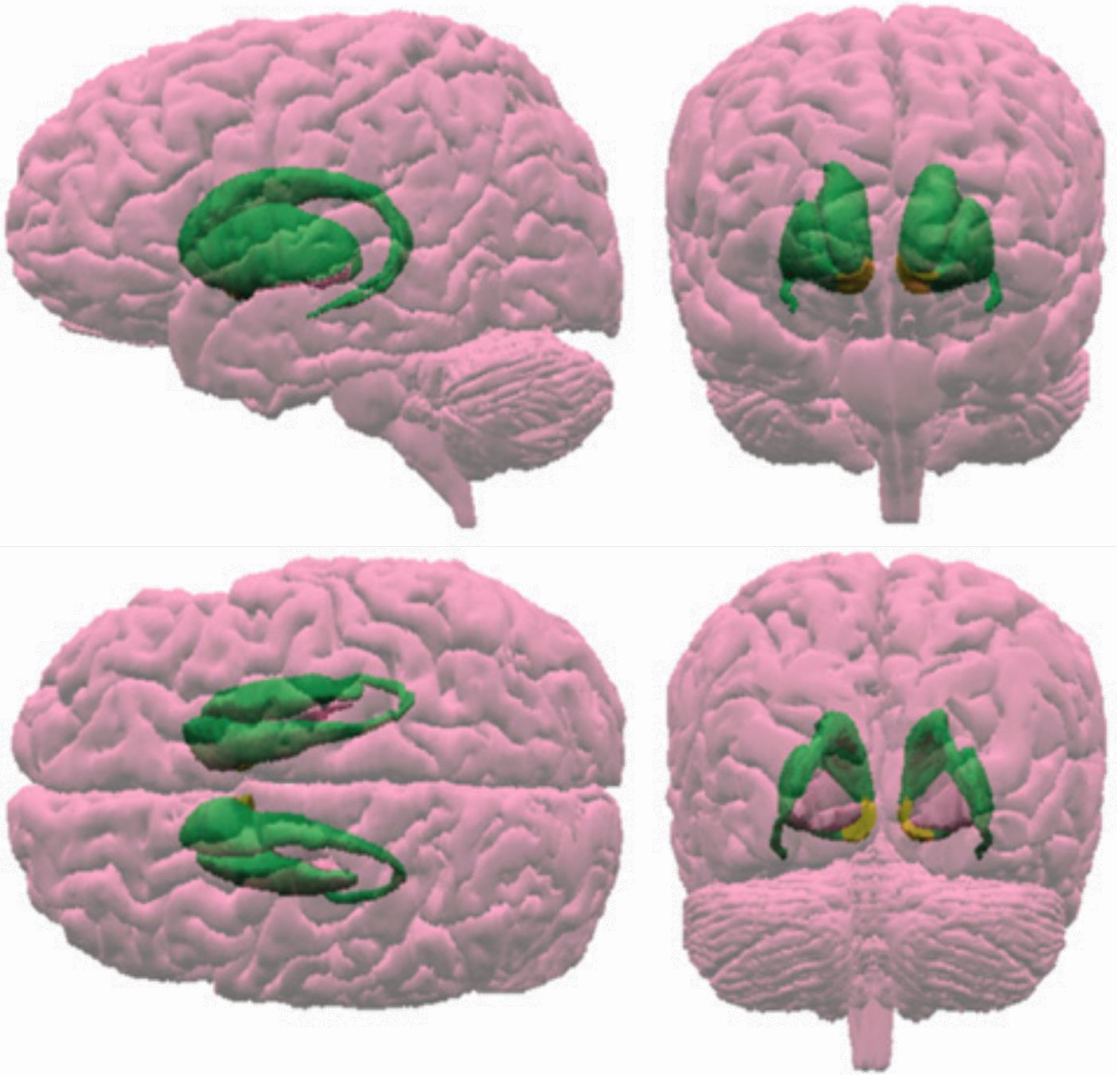
Blumenfeld, 2002

Thalamus – well connected





Basal Ganglia

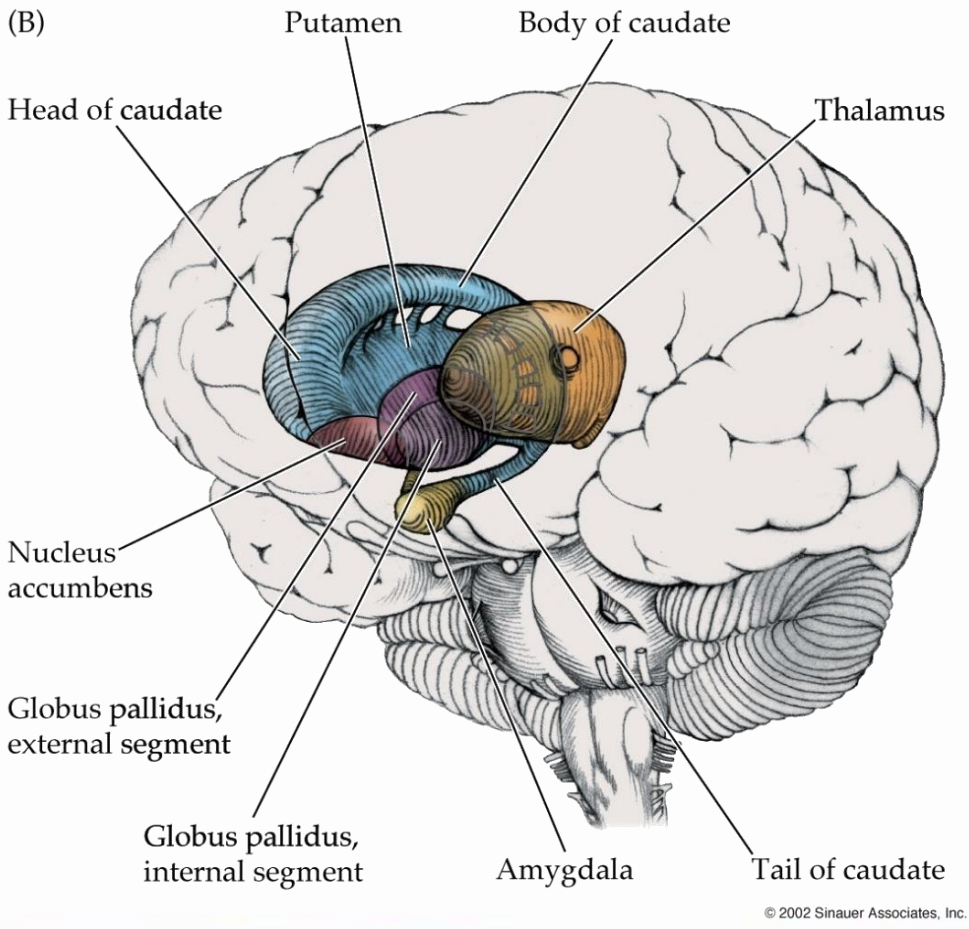


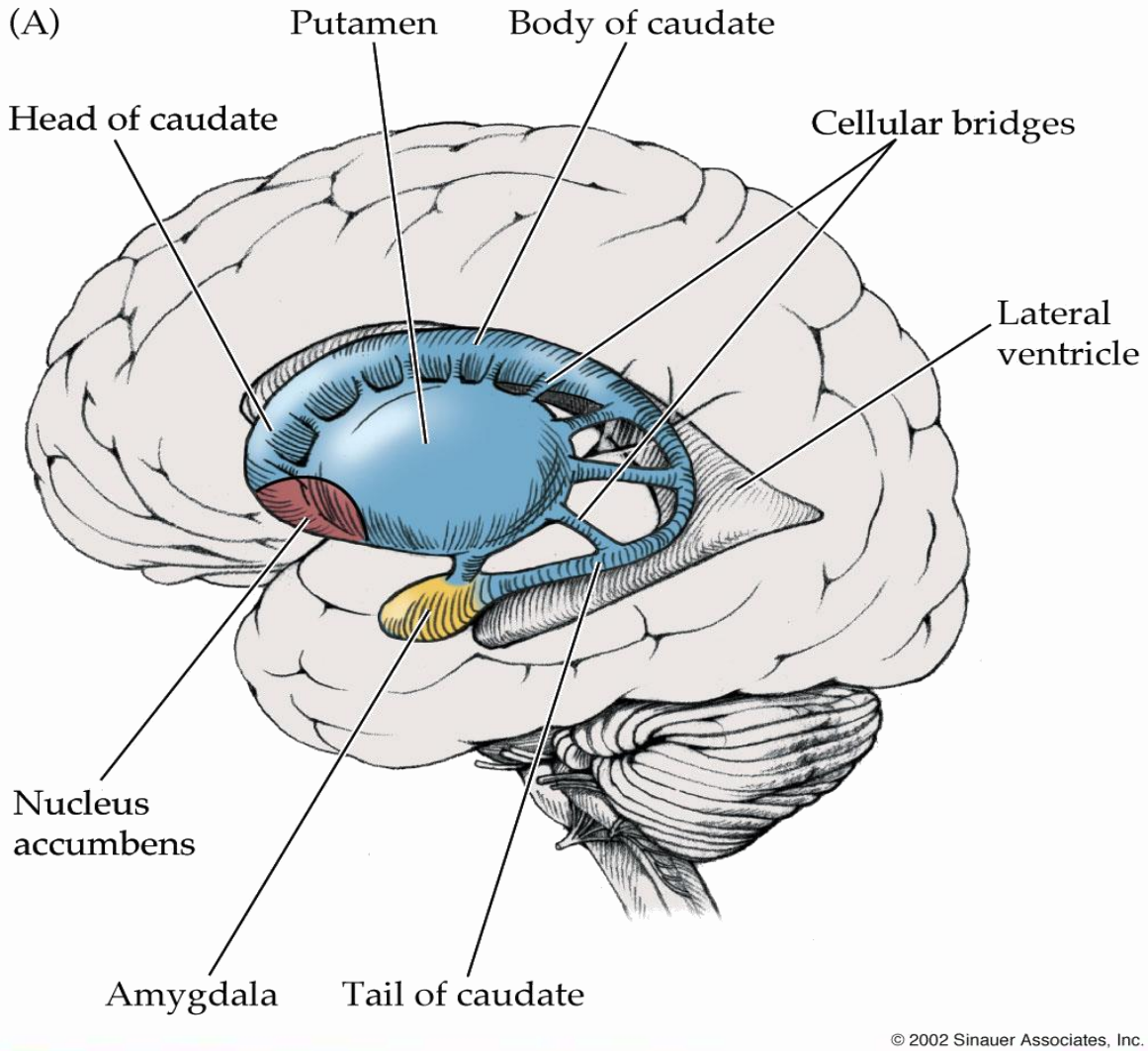
Nolte Figure 19-5

Nolte, 2002

Basal Ganglia

Figure 16.1

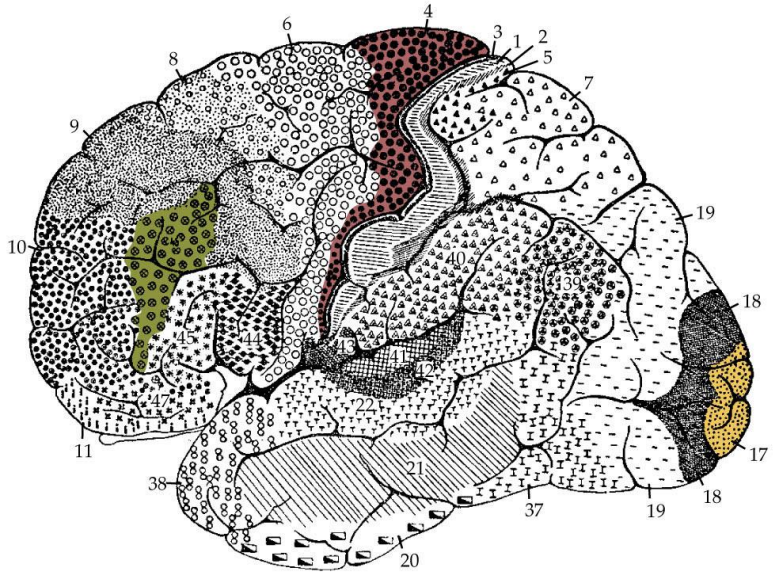


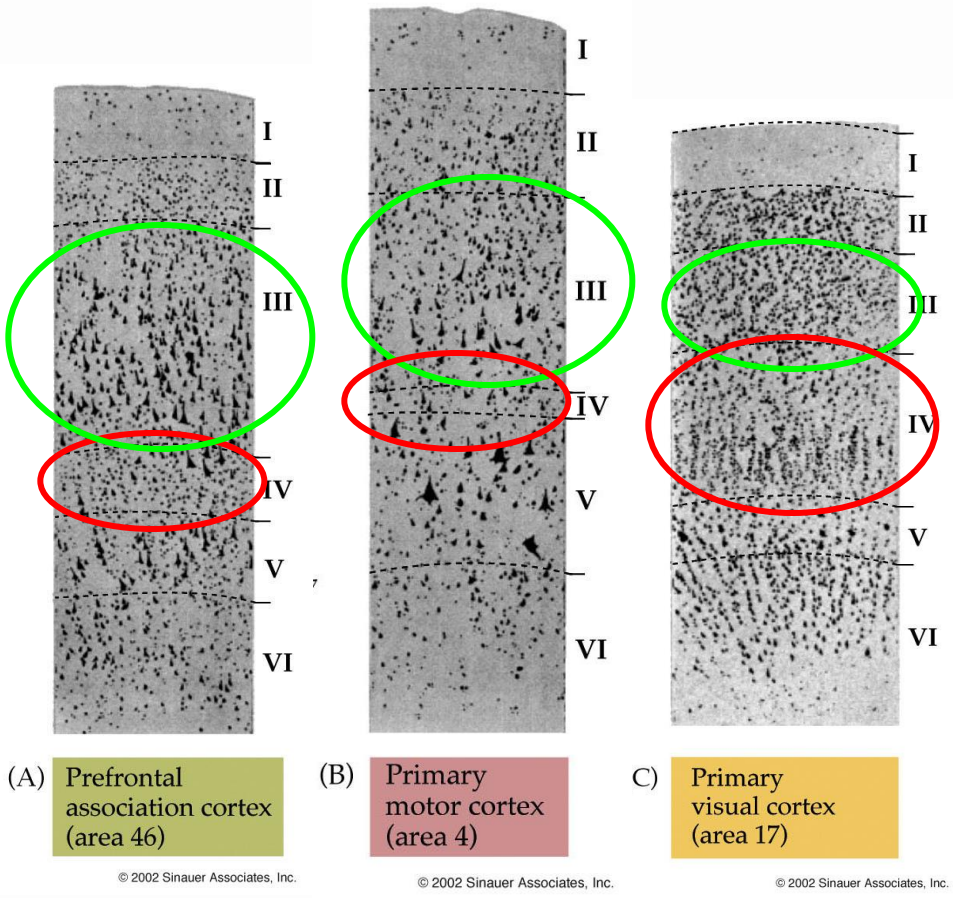


Blumenfeld, 2002

Cortex is organized in layers and columns

Figure 2.14



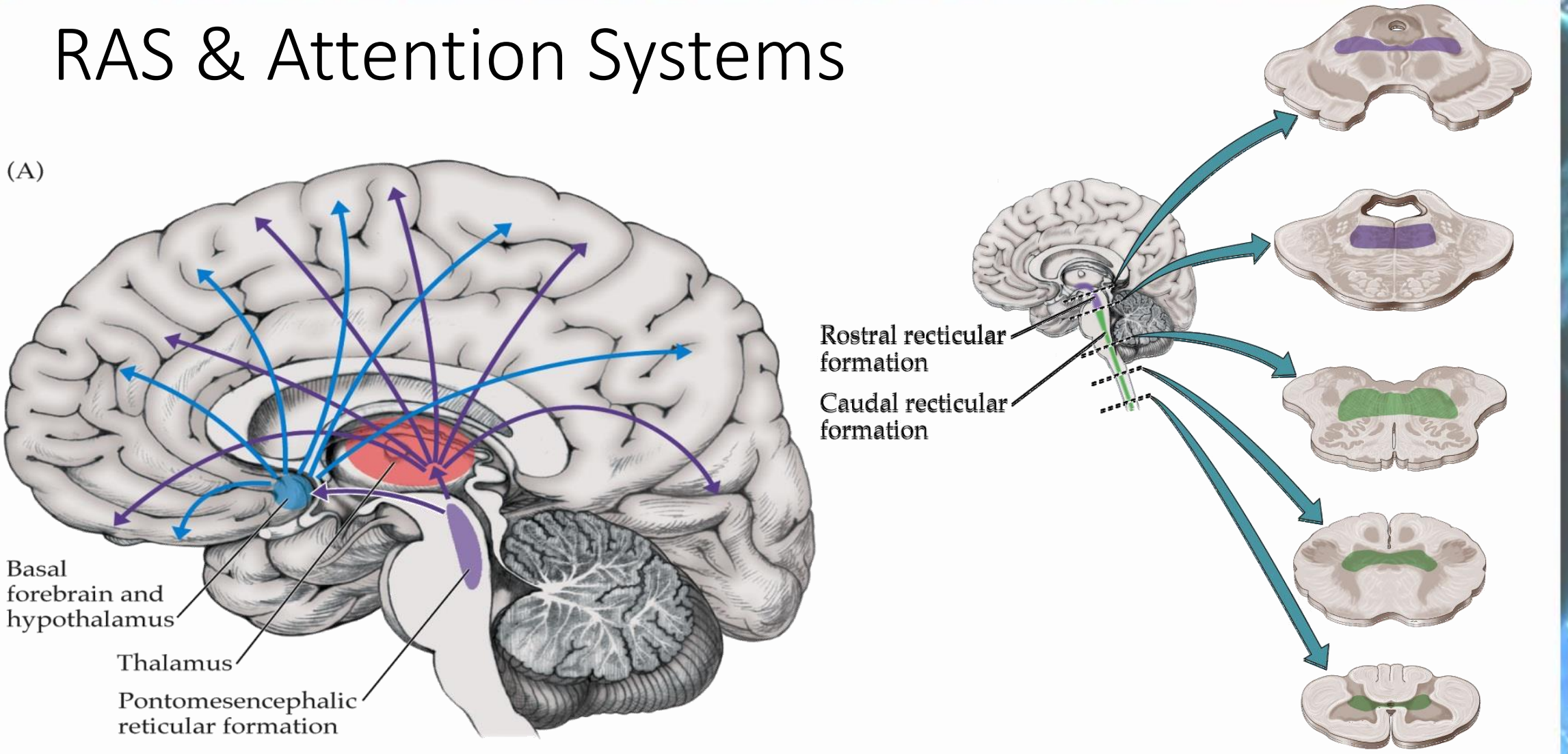


Layer III cortical-cortical connections

Layer IV thalamo-cortical connections

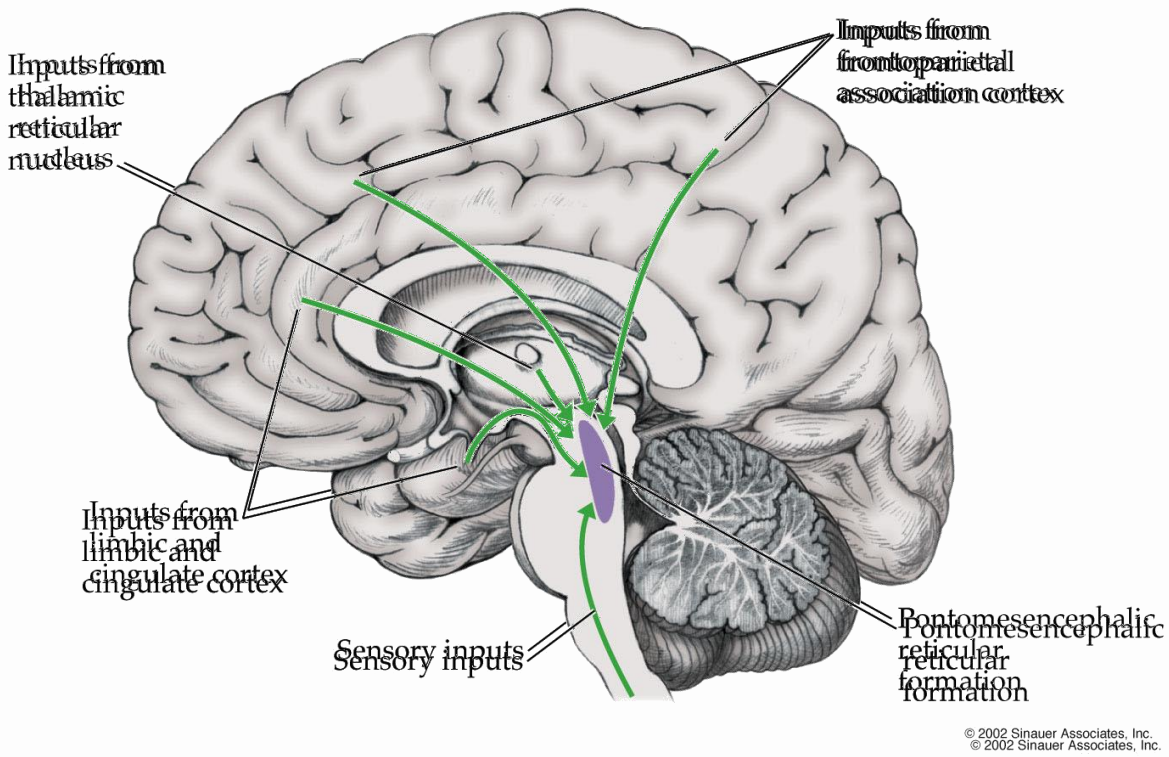
Blumenfeld, 2002

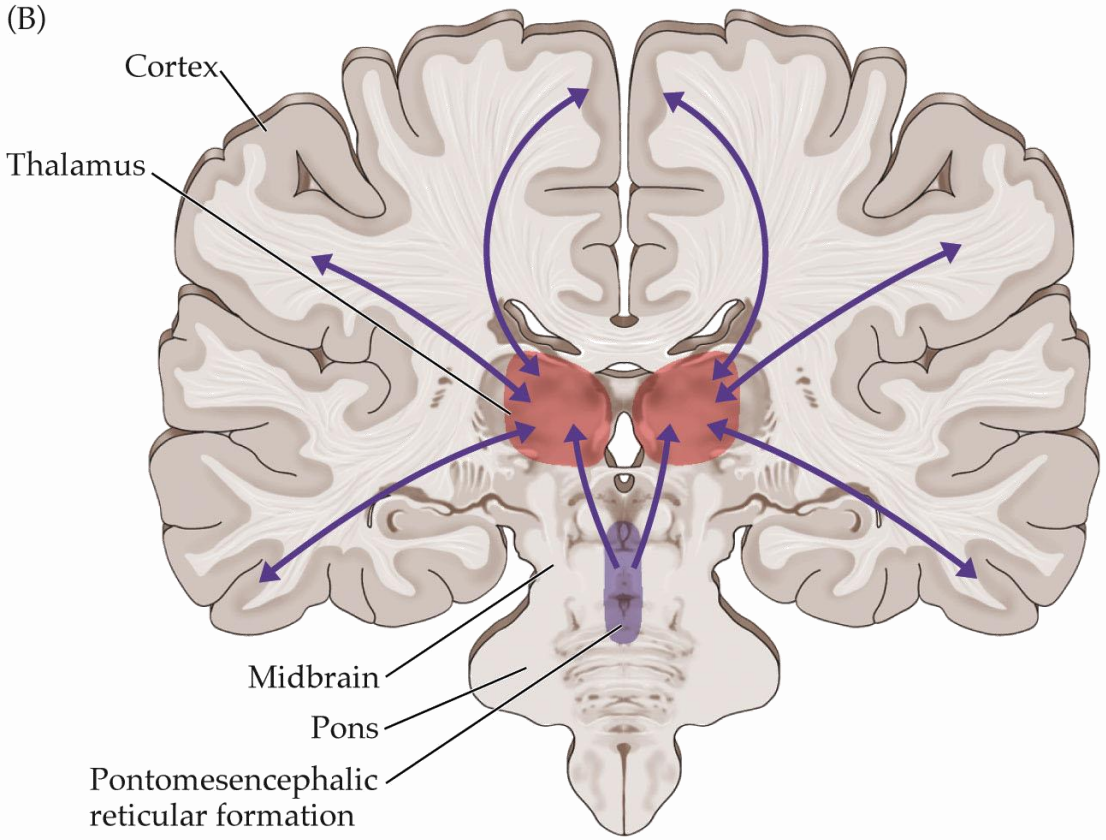
RAS & Attention Systems



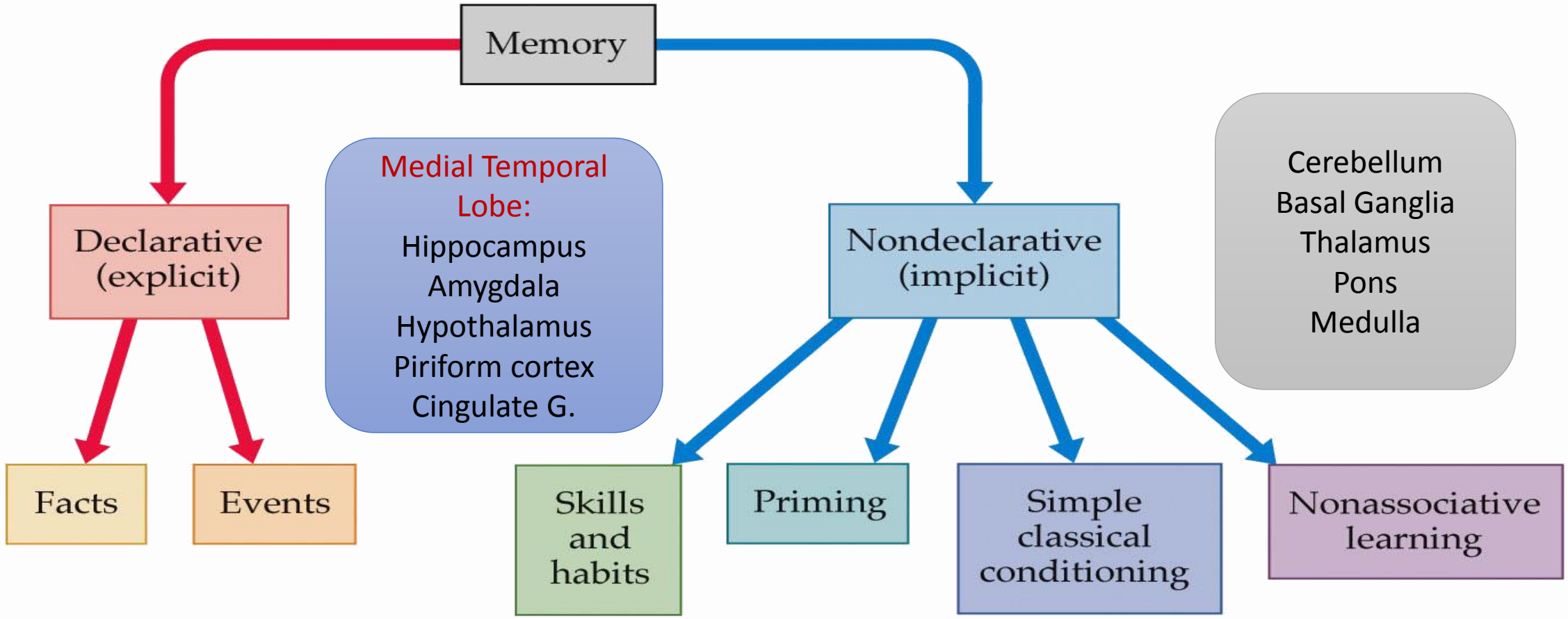
Filey, 2002; Blumenfeld, 2000

RAS continued…





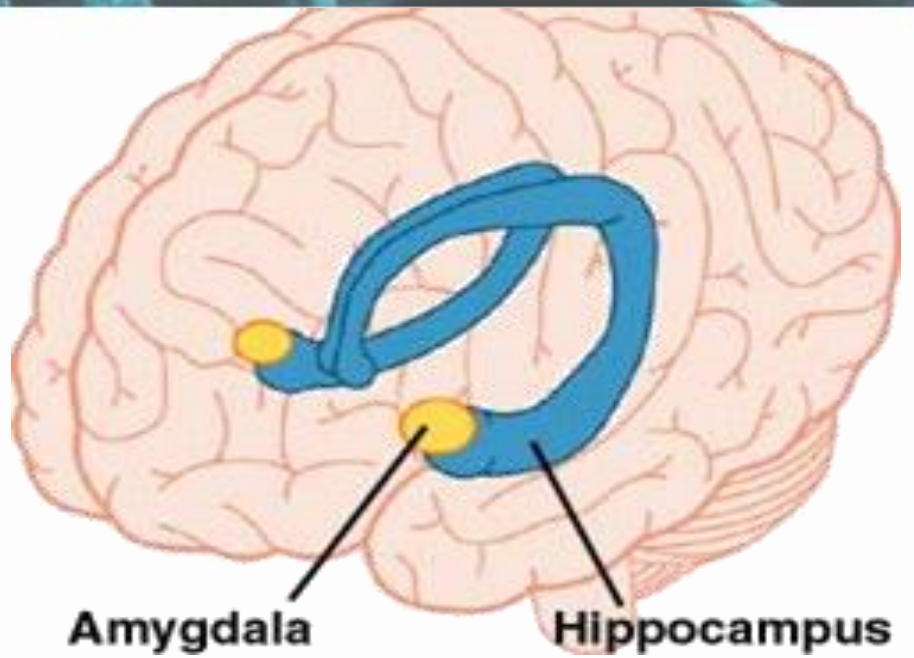
Memory Systems

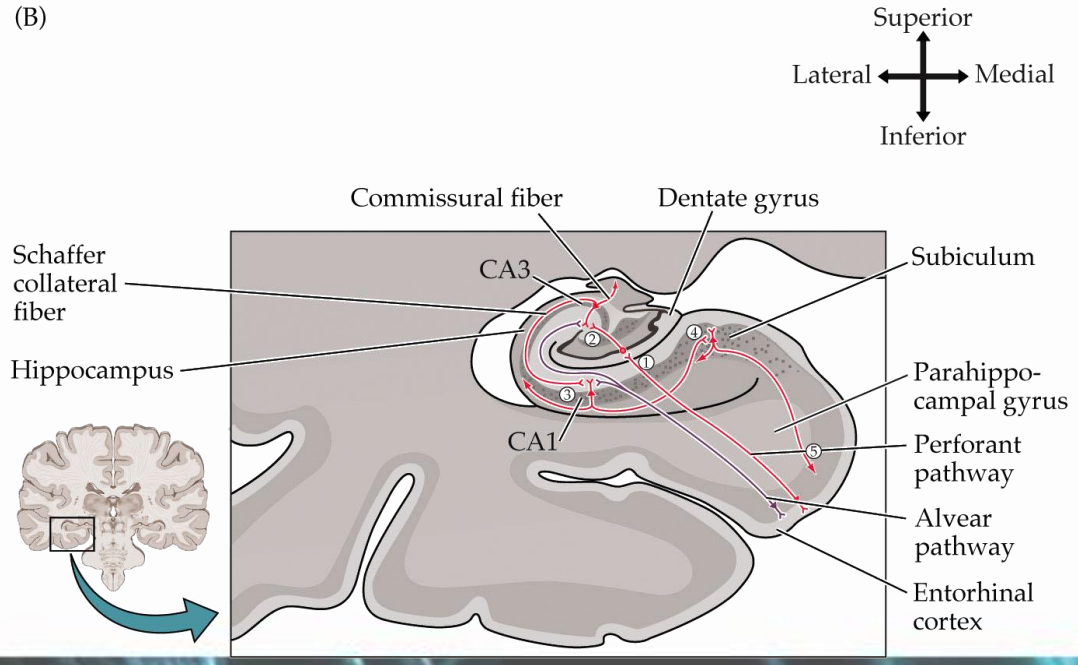


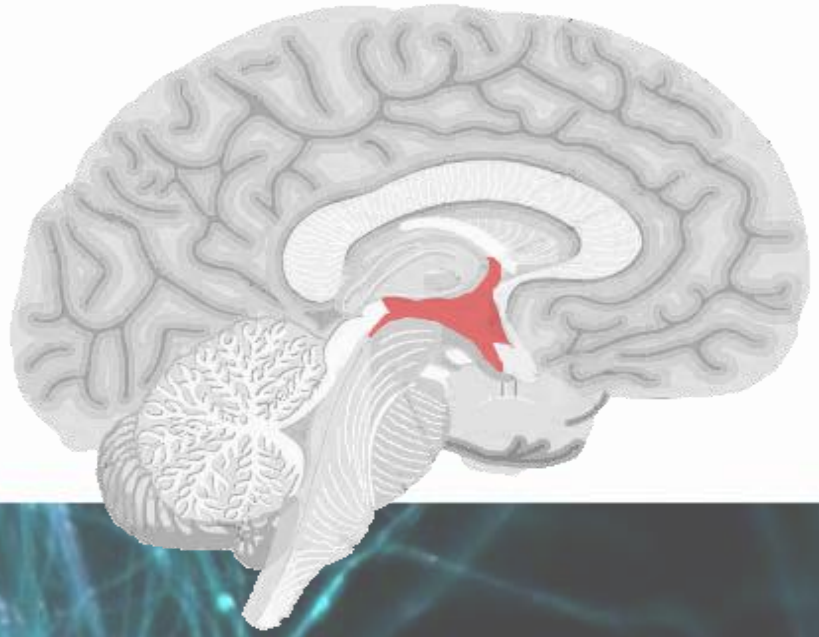
(After Squire LR, and Zola-Morgan S. 1991. The medial temporal lobe memory system. Science 253: 1380-1385.)

Blumenfeld, 2002

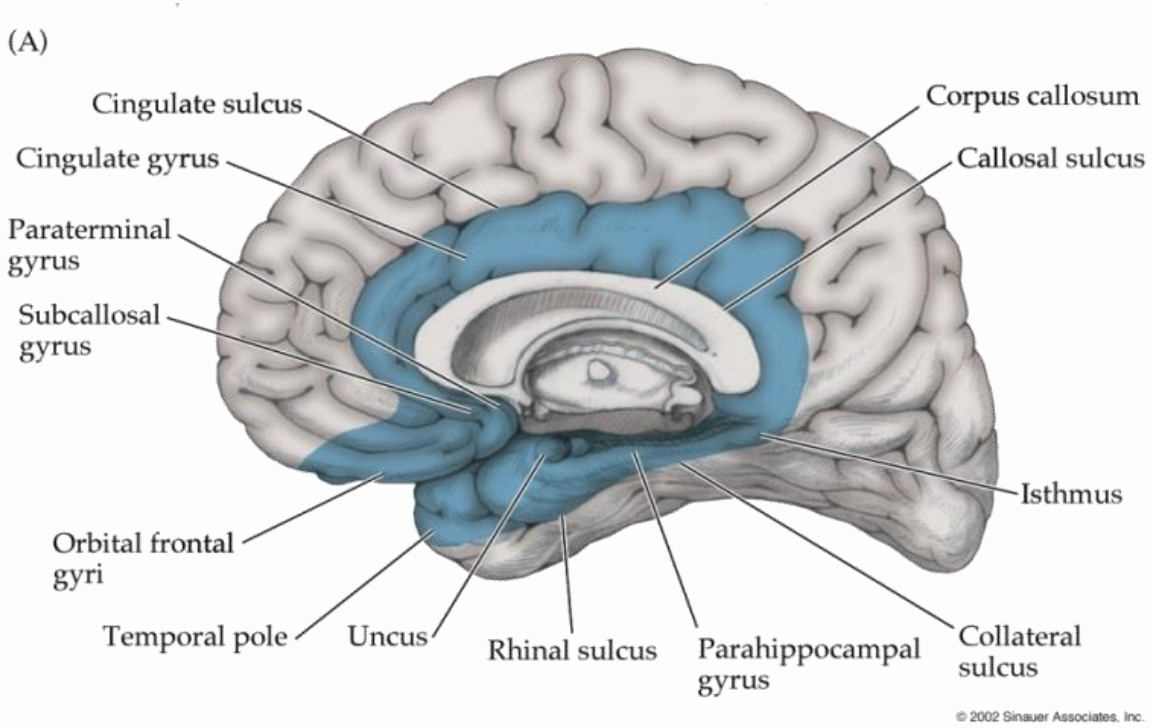
- H – Homeostasis (hypothalamus et al.)
- O – Olfaction (olfactory cortex, entorhinal, pyriform, et al.)
- M – Memory (hippocampus, amygdala, et al.)
- E – Emotions (amygdala et al.)

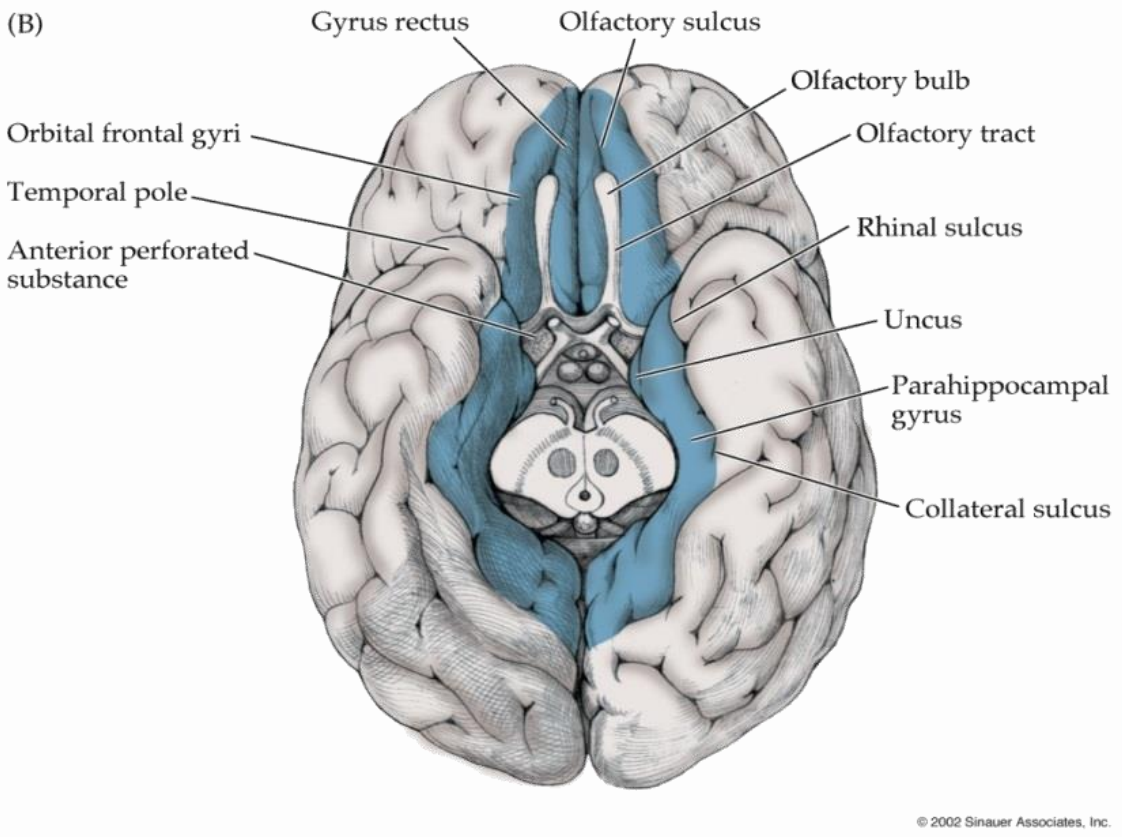






Limbic cortex

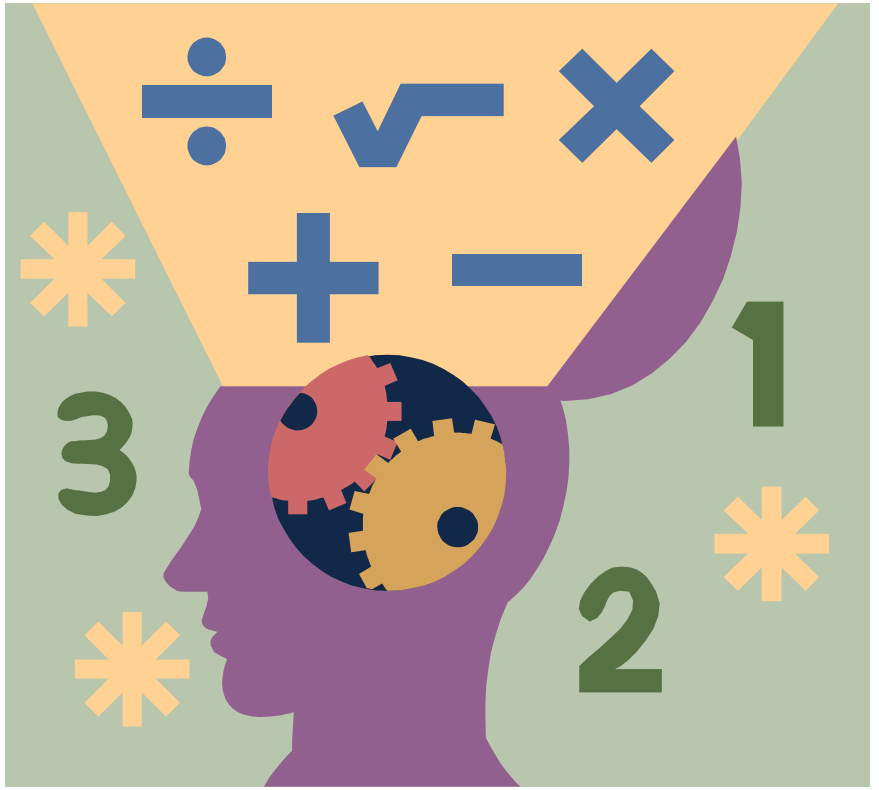




Blumenfeld, 2002

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

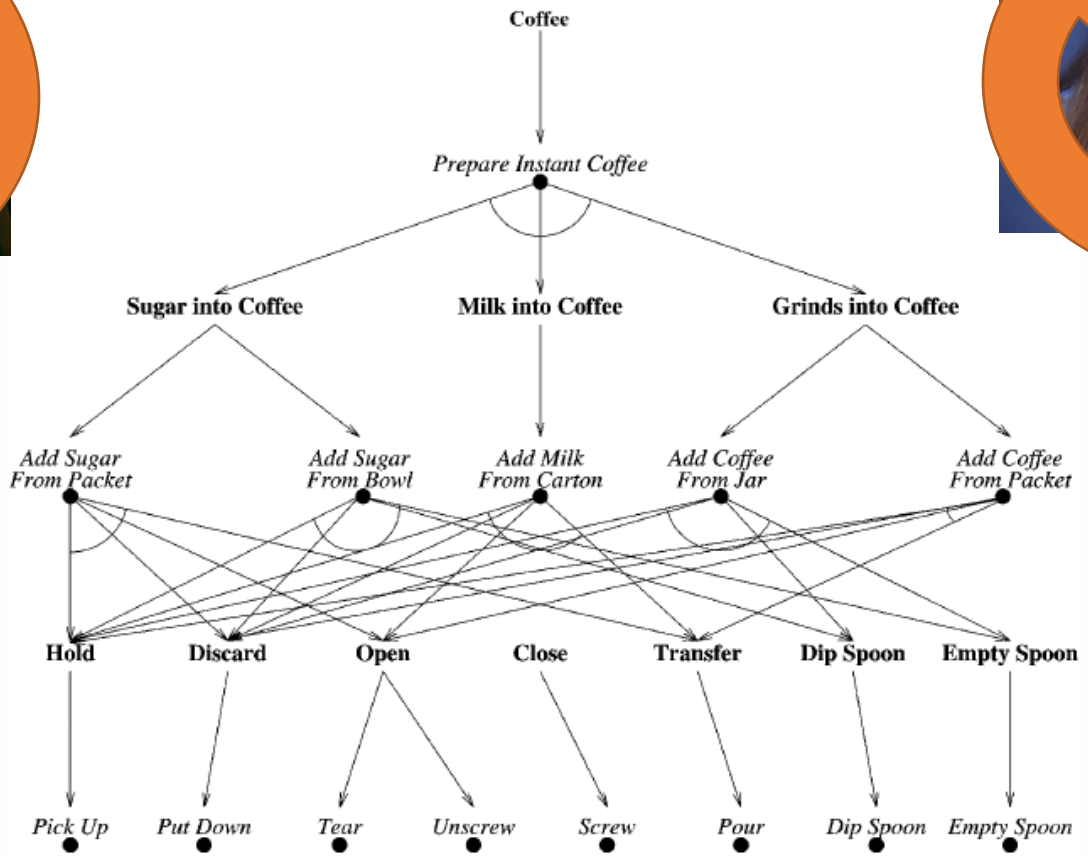
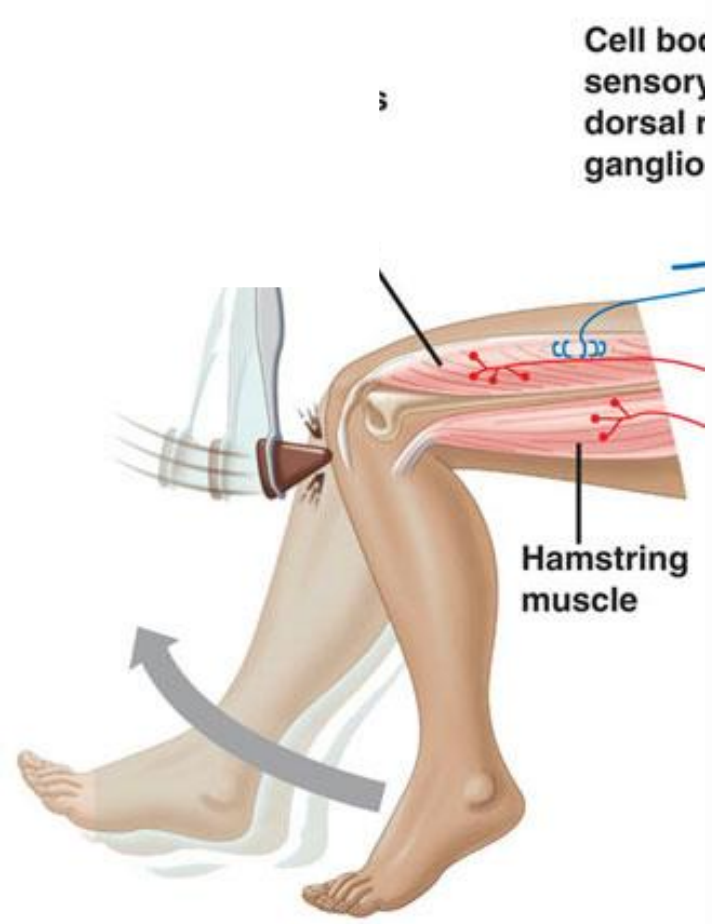


Fig. 2. *Schema/goal organisation in the coffee preparation domain. Schemas are indicated by italic type and goals by bold type.*

Mesulaum's Default Model

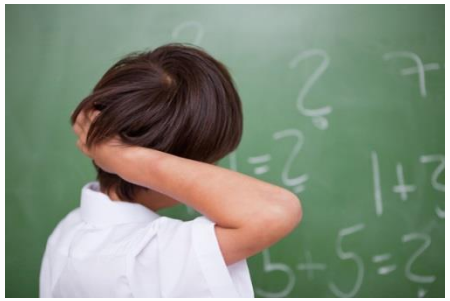
- To make a decision about a novel event we must inhibit our default/knee jerk response
- Default response doesn't initiate working memory or problem solving



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



MacDonald & Christiansen, 2002

Guess what?

- Domain-general tasks place high demands on working memory

Horn & Hoffer, 1992

Inhibition-Default

Novel

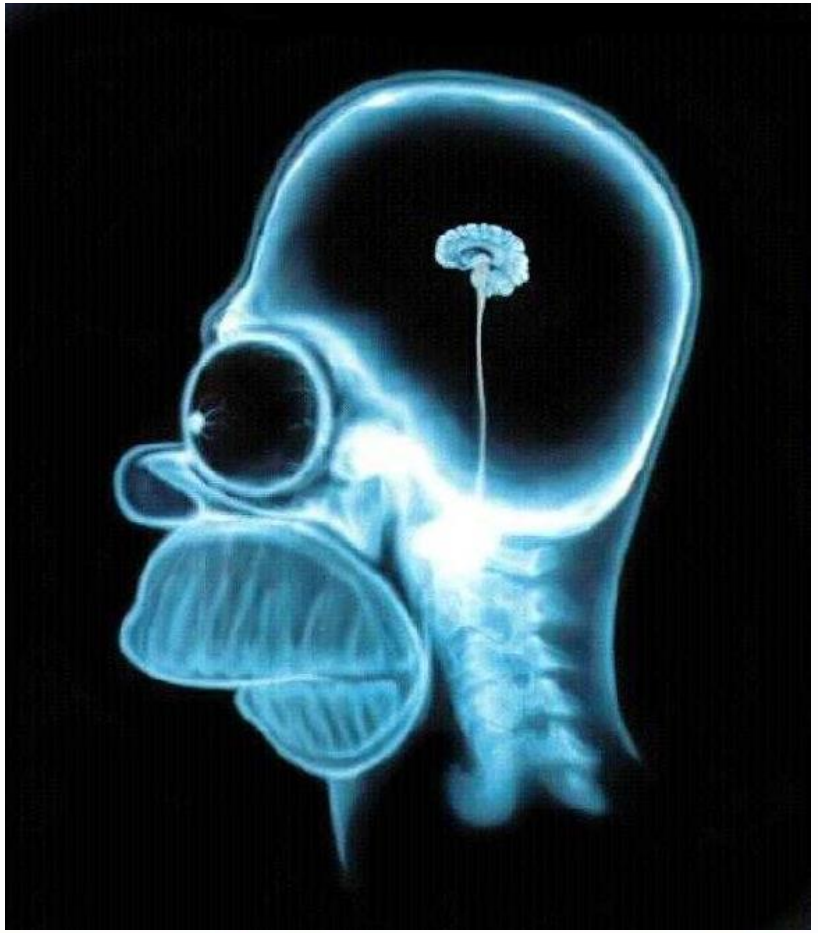
- Engage working memory
- Inhibit tendency to remain in routine, automatic mode

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)



Damasio, Bechara, Tranel, & Damasio

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…

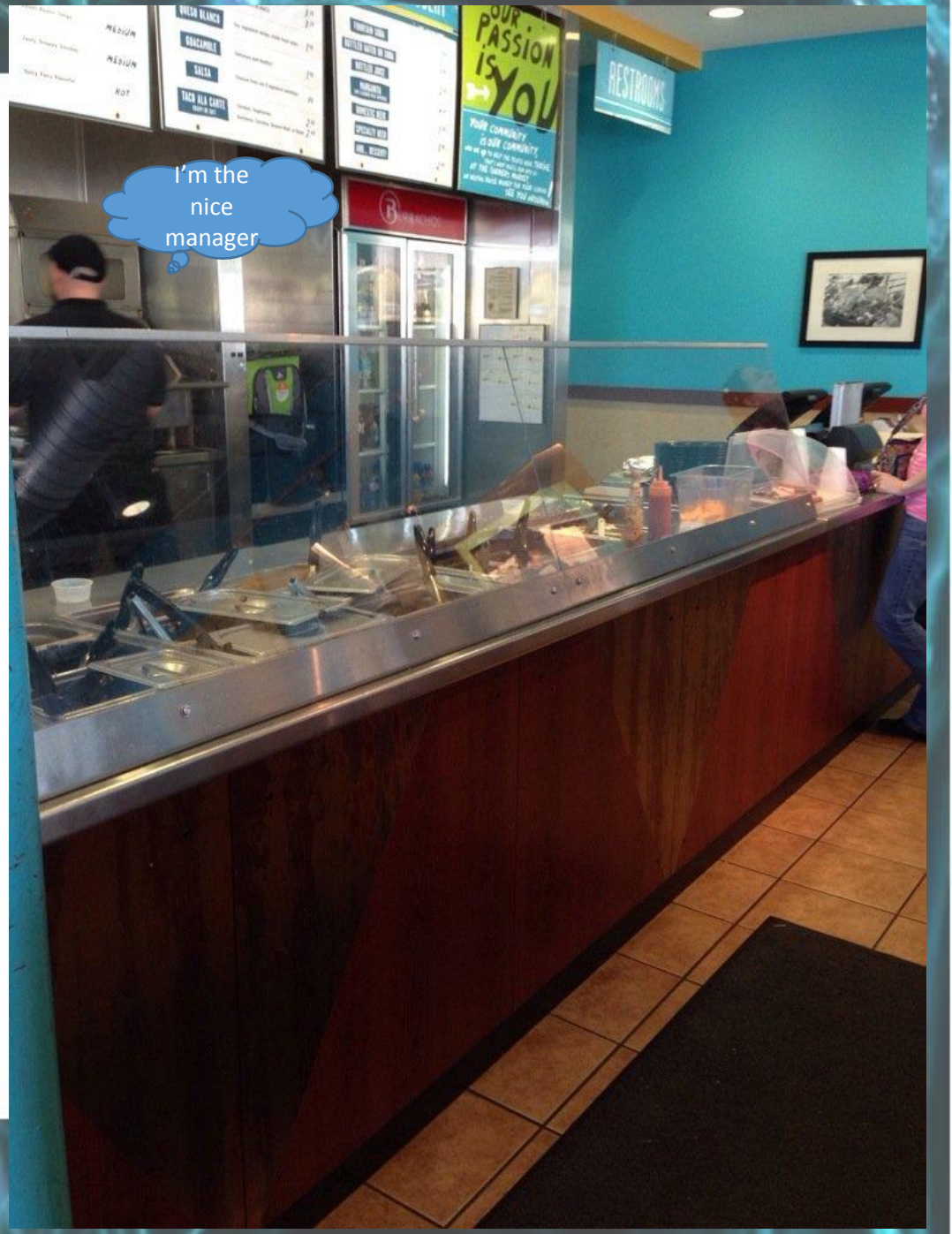
Why cognitive rehabilitation through metacognitive training rather than social skills training?

- 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)

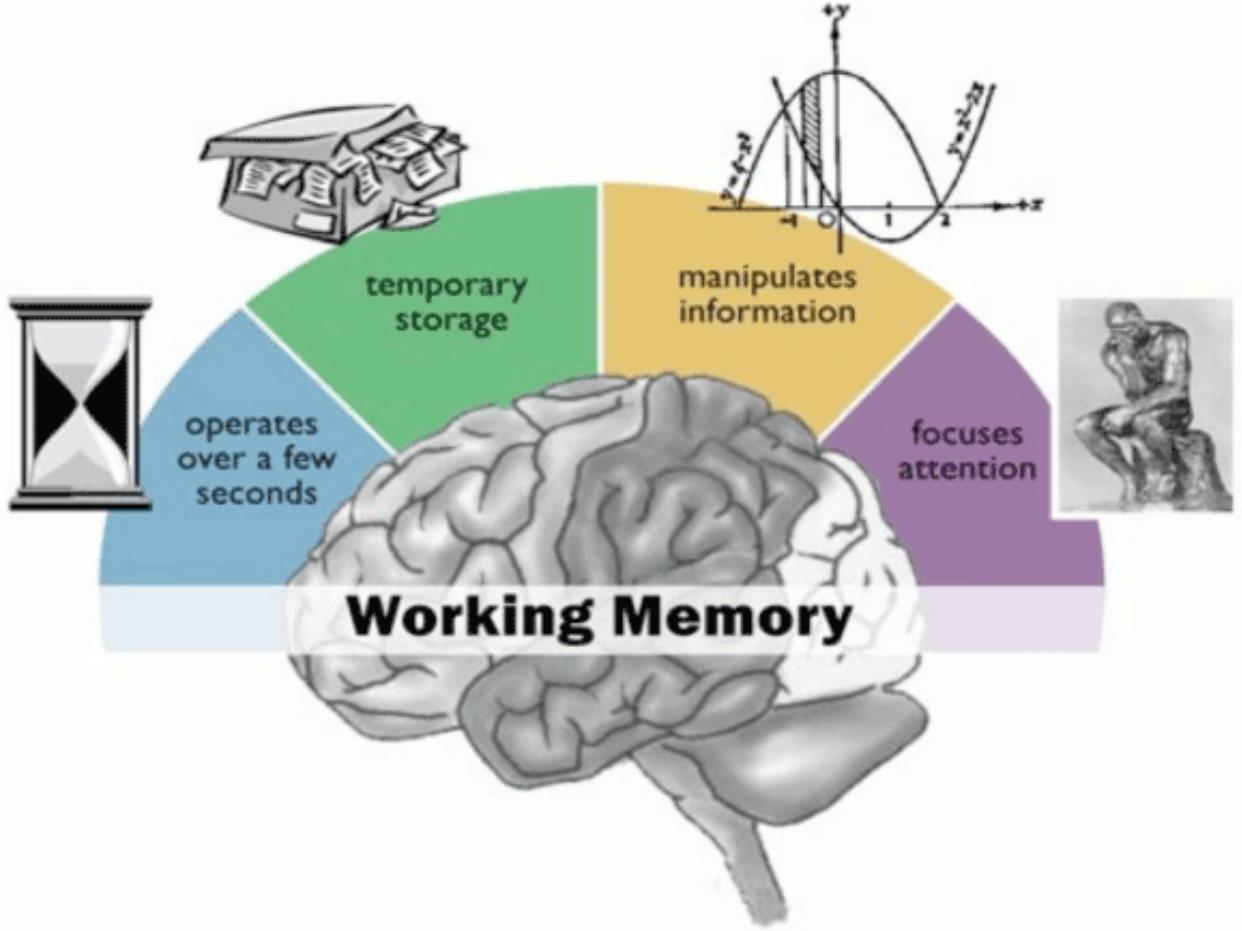
Dahlberg et al., 2007; McDonald, Tate, Togher, Bornhofen, Long, Bertler, & Bowen, 2008

Burrachos example

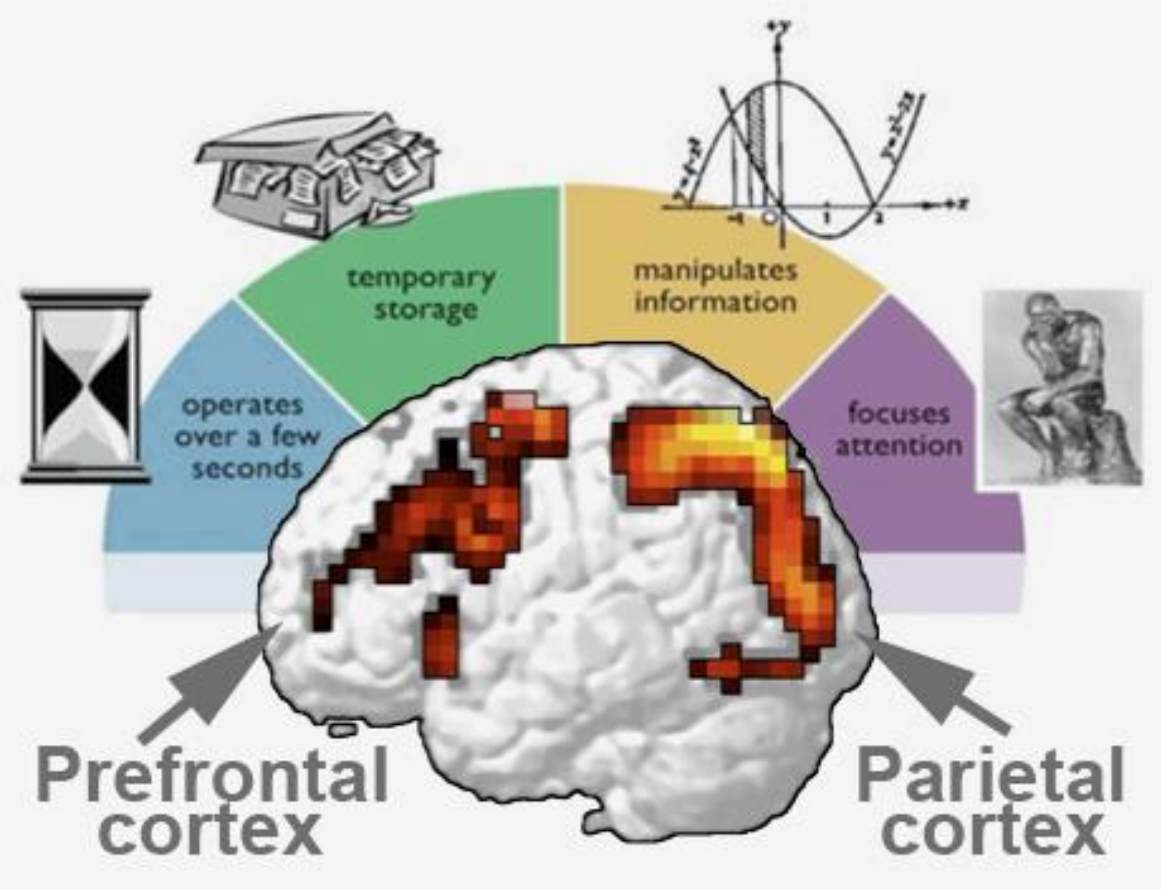
- How do we get to the precipice?
- It may be closer than you think…
- Consider what factors move you towards the threshold…

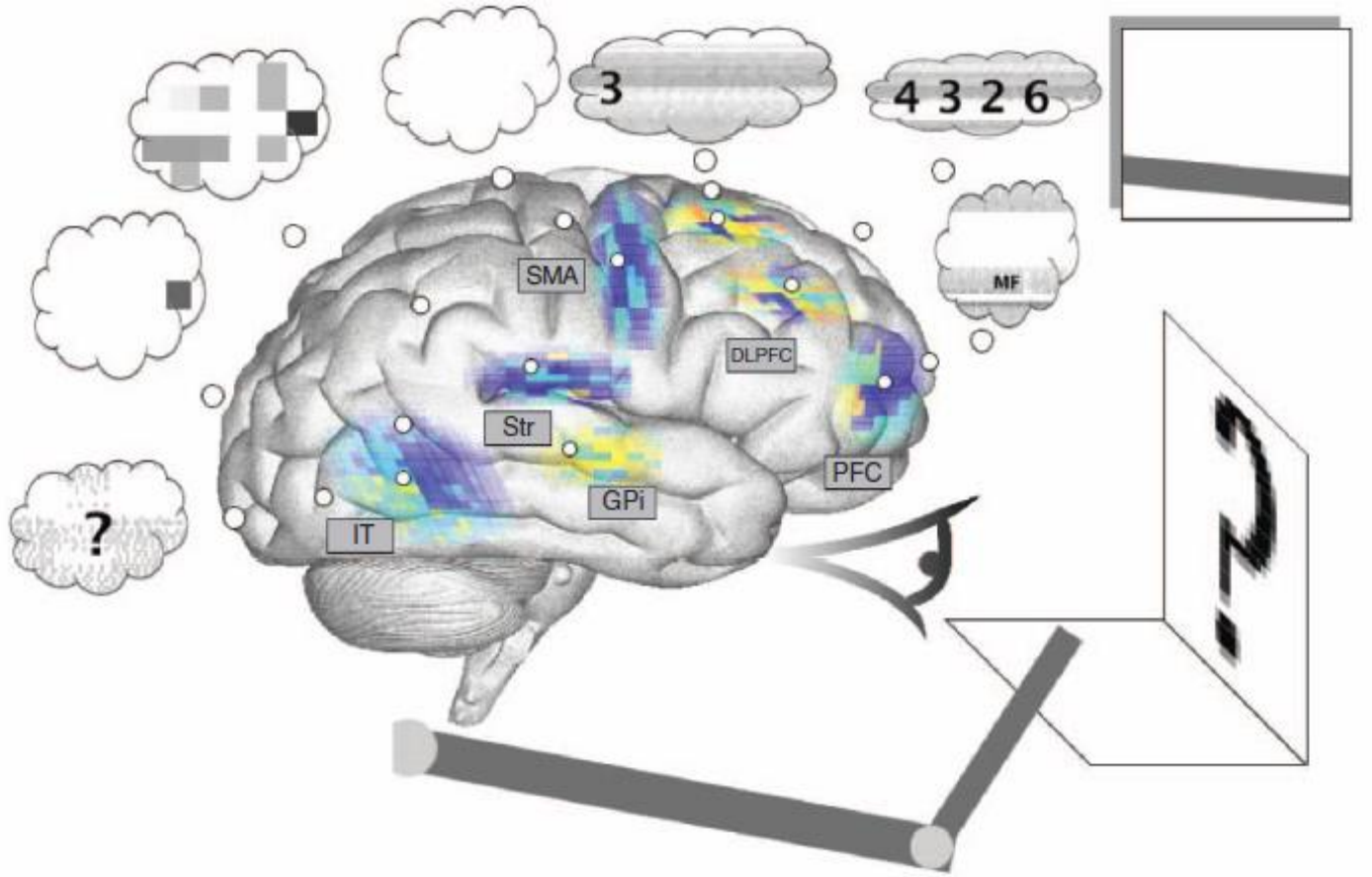


What is working memory?

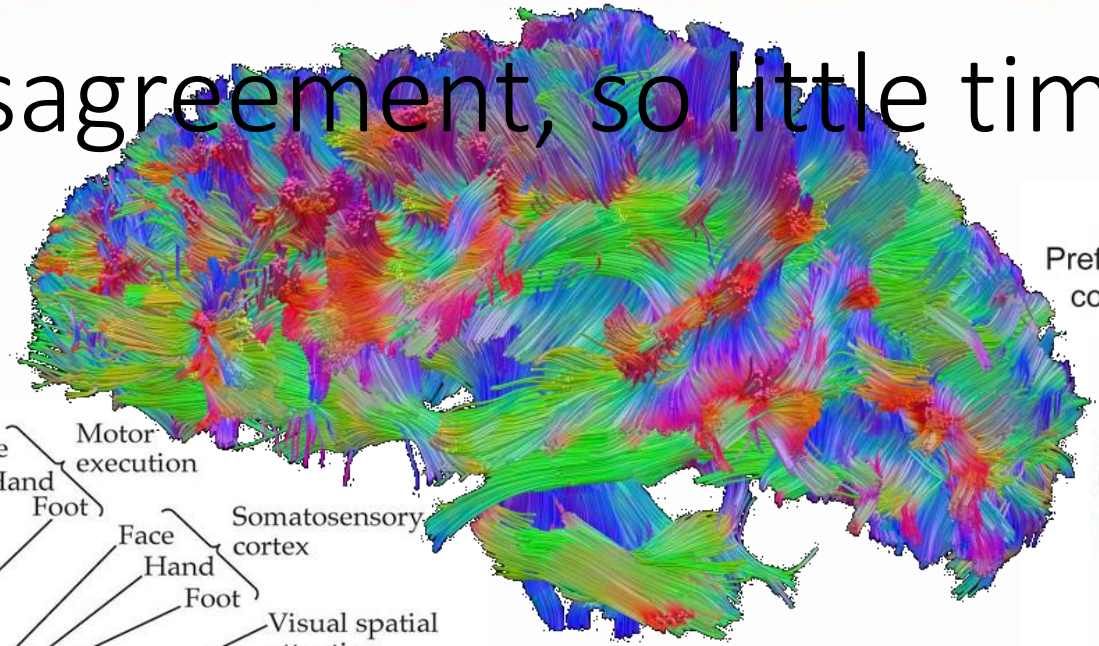


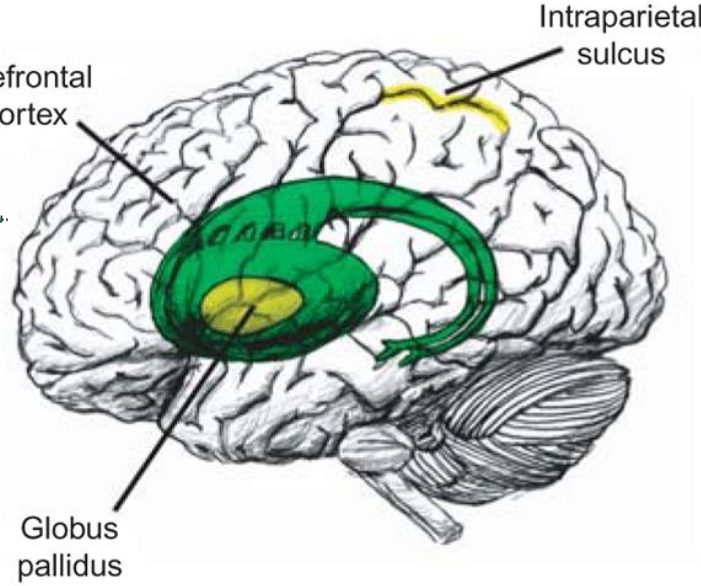
Discrete???

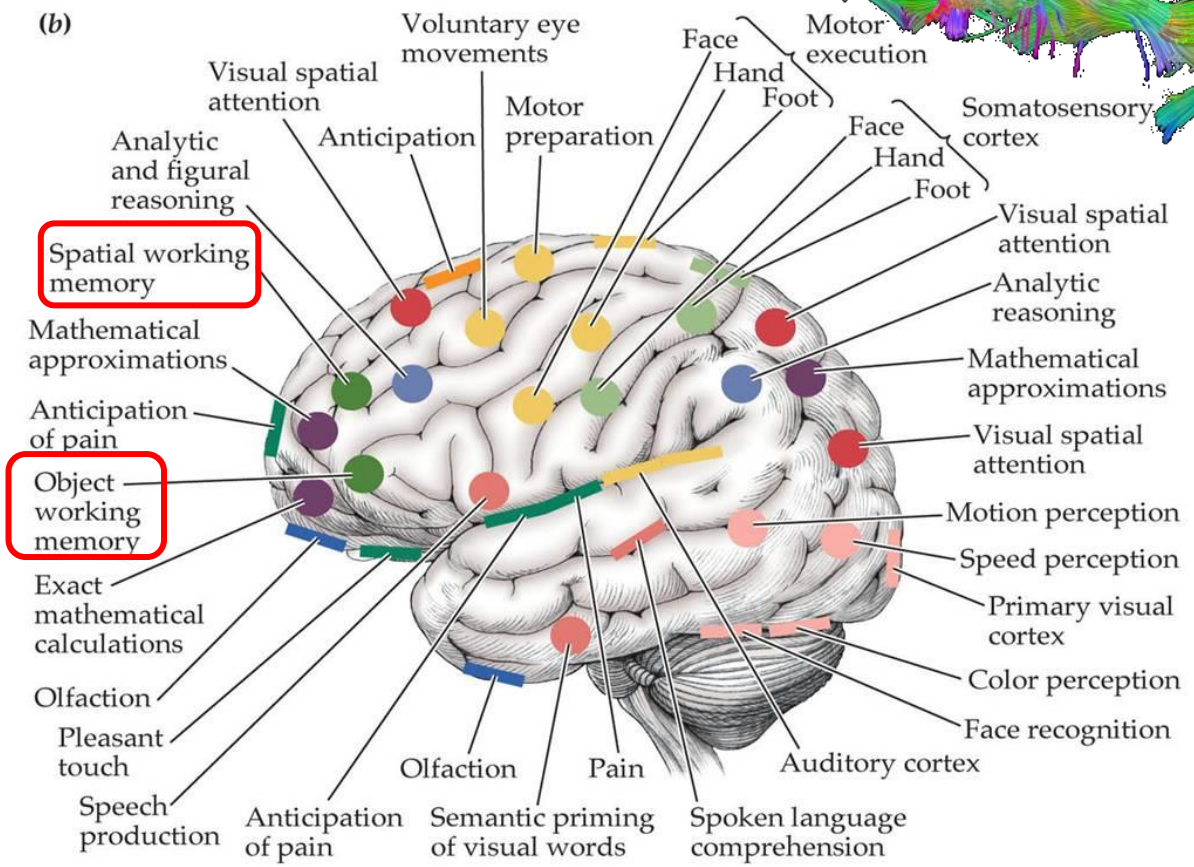

temporary storage
manipulates information
operates over a few seconds
focuses attention
Prefrontal cortex
Parietal cortex


3
4 3 2 6
SMA
MF
DLPFC
Str
PFC
GPi
IT
?
?

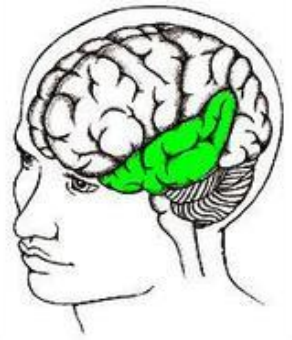
So much disagreement, so little time…







Phonological loop - temporal lobes of the left hemisphere

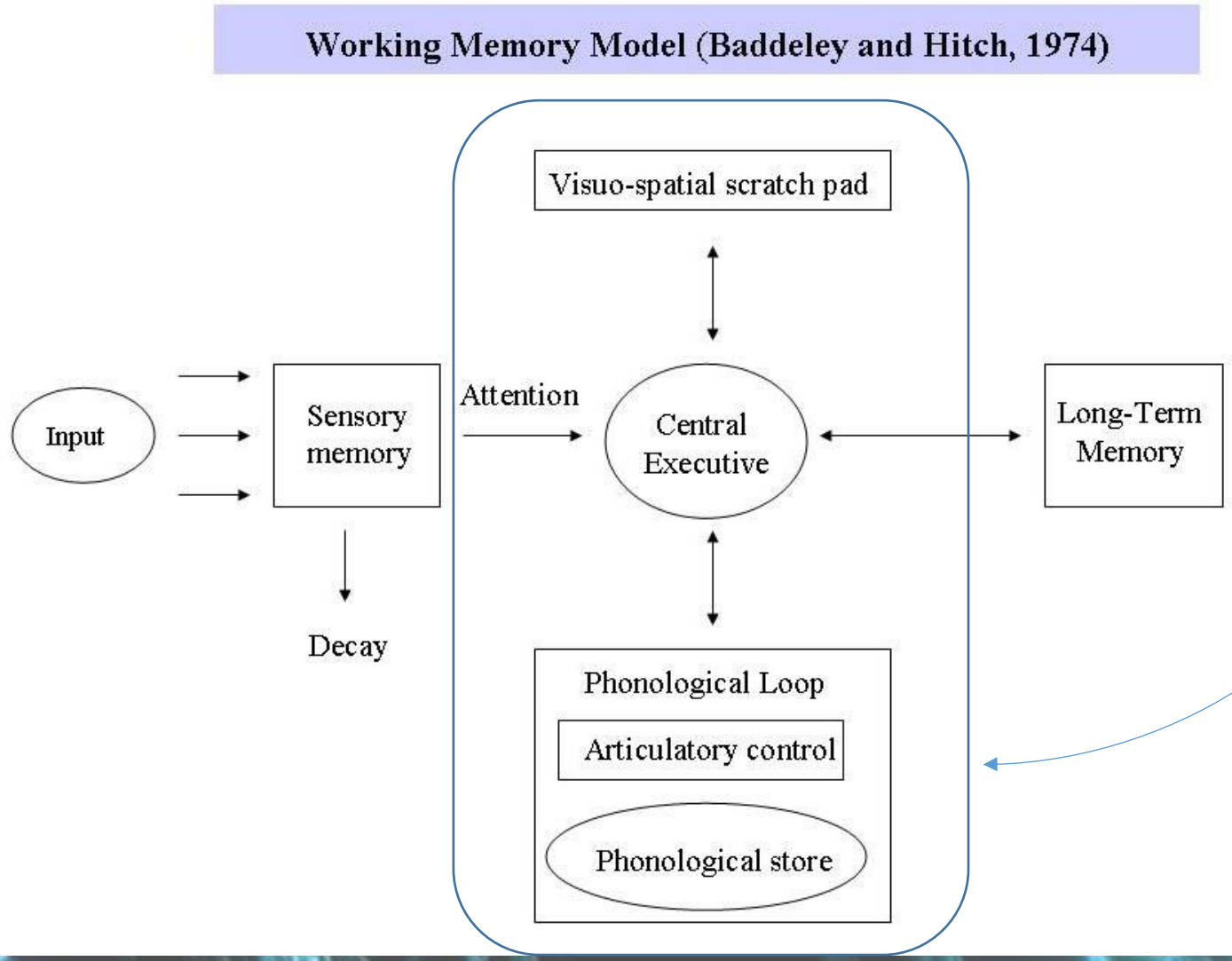


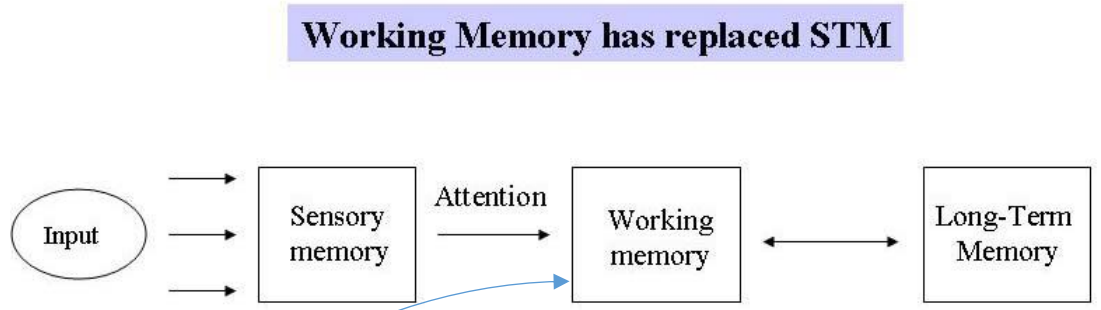
Visuospatial memory – right hemisphere

Central executive – dorsolateral prefrontal cortex

Working memory is…
[In very simple terms]

Baddeley & Hitch (‘74, ‘86, ‘92)





Just & Carpenter (1992)

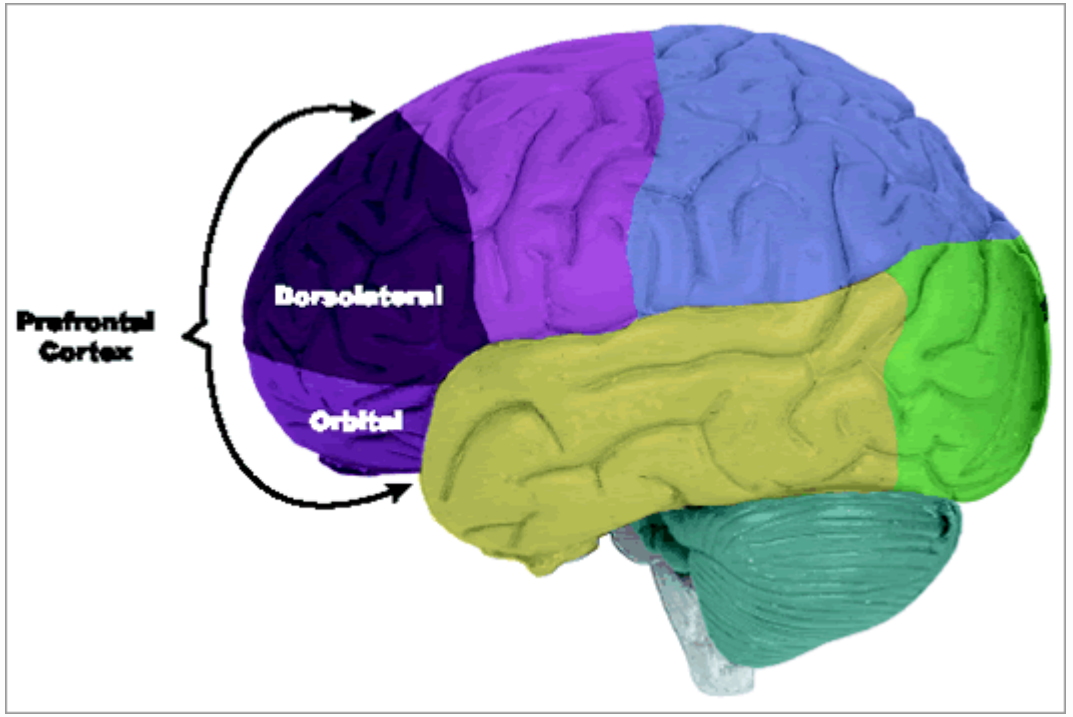
- Limited capacity
- Activation matters (capacity is dependent on attention)
- Resource reallocation
- Over doing it leads to across-the-board budget cuts (slows and deteriorates processing)
- Simultaneous activation in those with big budgets

Hasher & Zachs (1988)

- Limited capacity
- Sensitive to interference
- Better working memory is dependent on better inhibition and filtering!

And reality lies somewhere in between…

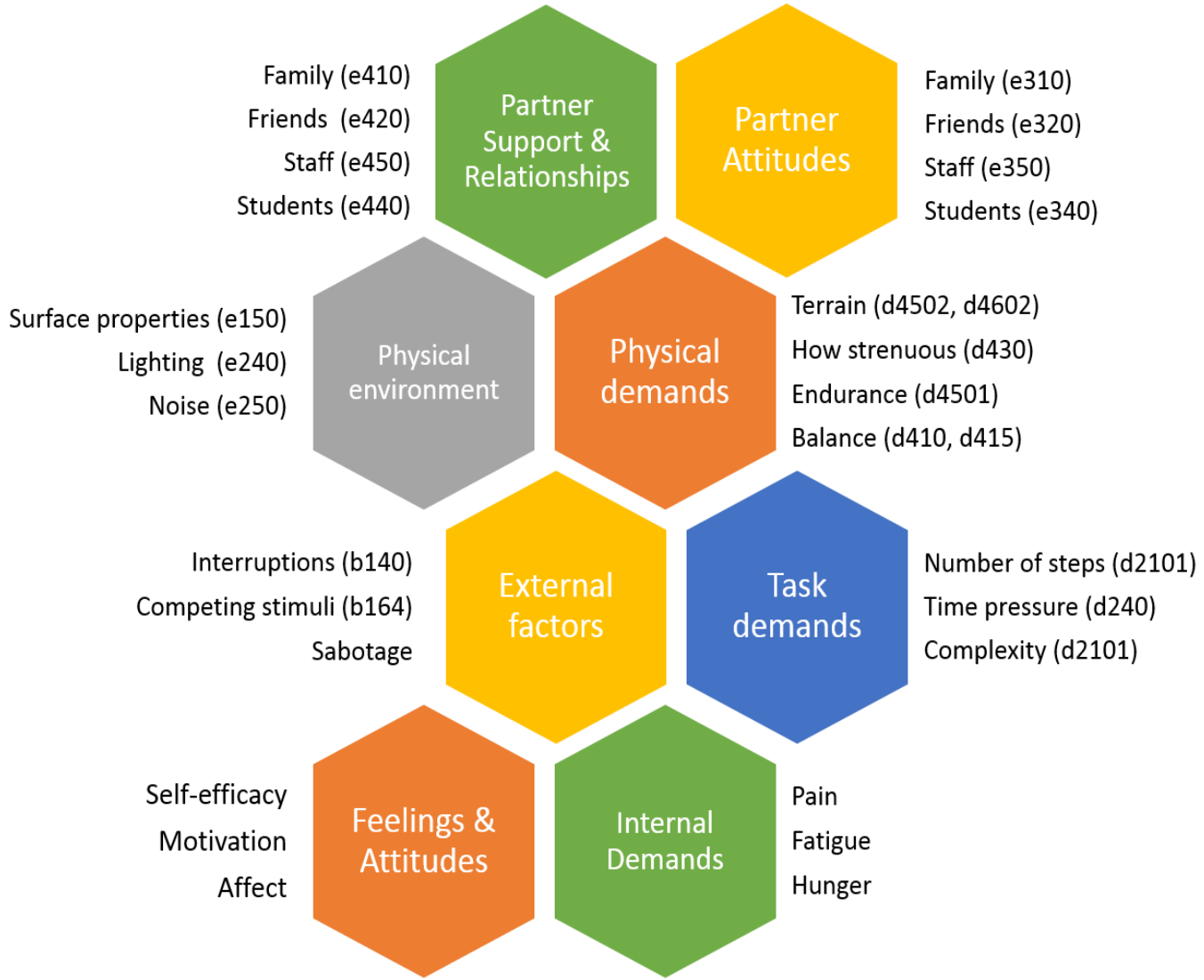
- The dorsolateral and orbital medial PFC are critical in executive control and inhibition for working memory
- No working memory functions are isolated



What happens when working memory becomes overloaded?

- Mind racing
- Frustration
- Anger
- Inefficiency
- Unproductive
- Spinning your wheels

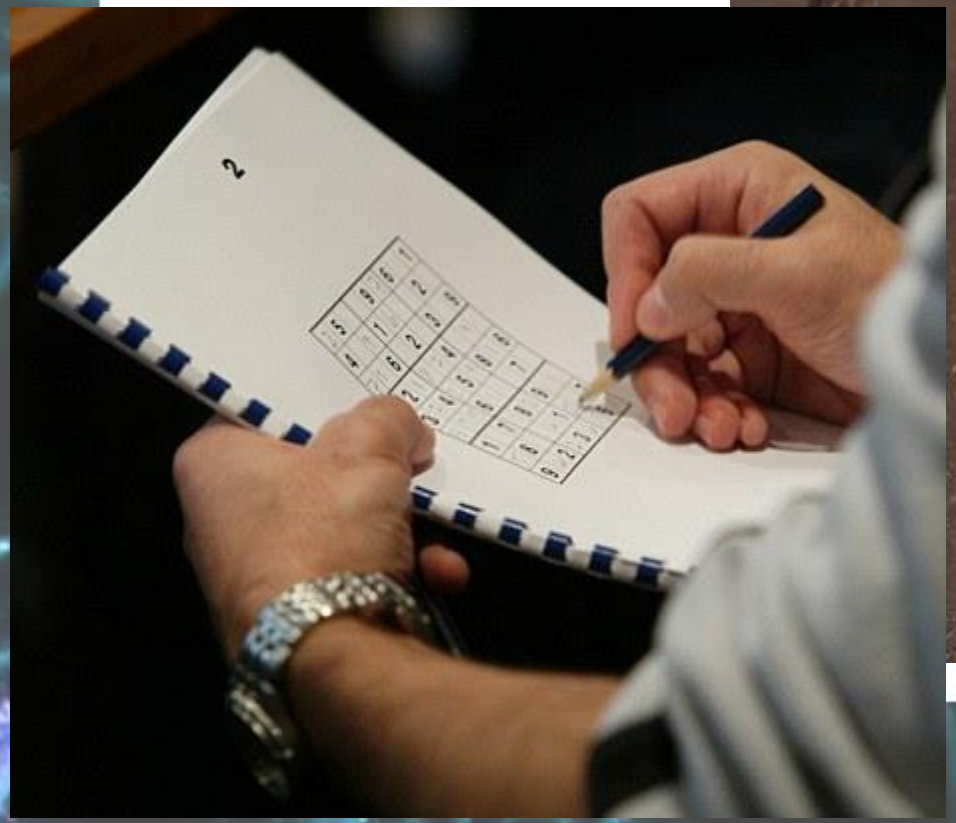
Contributors to overload…



Factors related to WHO-ICF

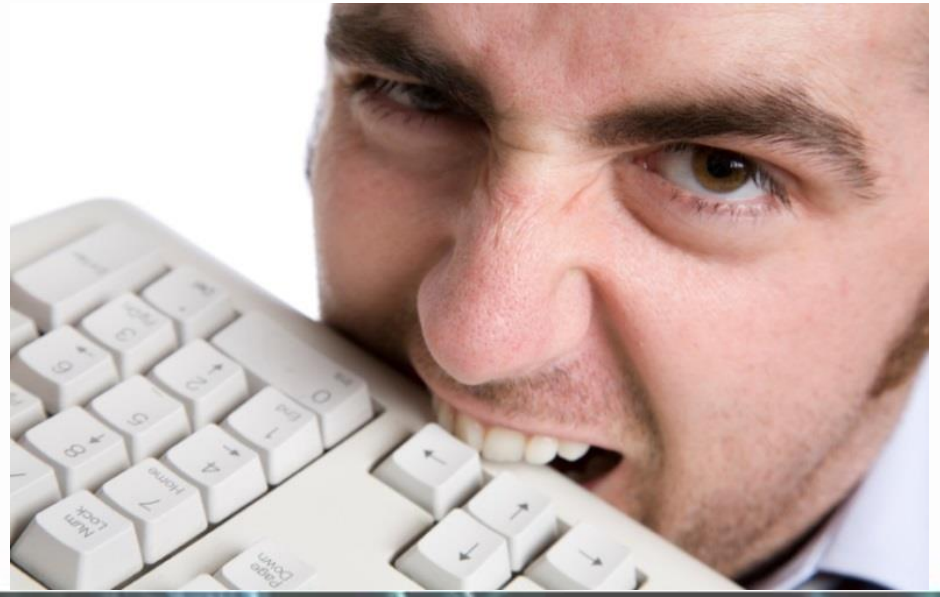
Hoepner, Buhr, Johnson, & Sather, in prep

Bart



Emotions…

- What happens to you when you get emotional?
- Have you ever had a discussion about an emotionally charged topic?



Emotions consume working memory resources

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

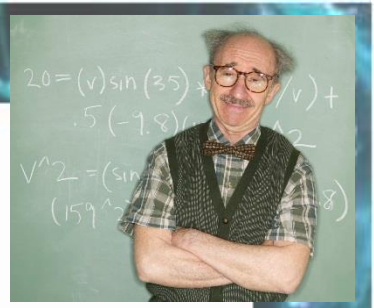
Addressing the paradox of assessing EF with standardized measures…

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.

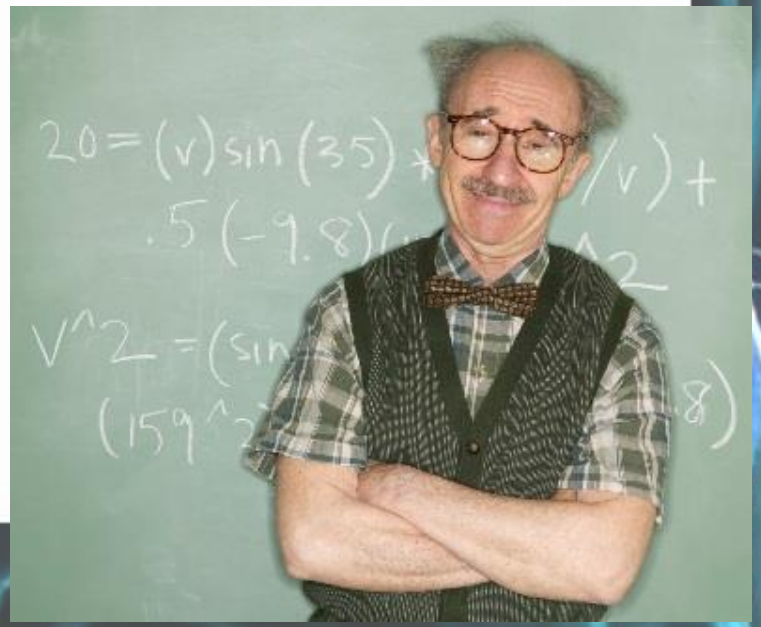
After a couple of months of outpatient day programming, Richard was ‘doing well’ and thinking about returning to work at the start of the next semester. A gifted professor, his colleagues were eager to make this work. They arranged a lighter load and some supports.

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?

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