

# Executive Function

Computational Cognitive Neuroscience  
Jessica Mollick, Randy O'Reilly

# Definition of executive function

- A process used to effortfully guide behavior towards a goal, especially in non-routine situations
- Multi-faceted, may include:
  - Inhibiting familiar/stereotyped behavior
  - Maintain an idea of which information is relevant right now
  - Resist distracting information
  - Switch between goals
- Definition from Banich, 09

# Very relevant example

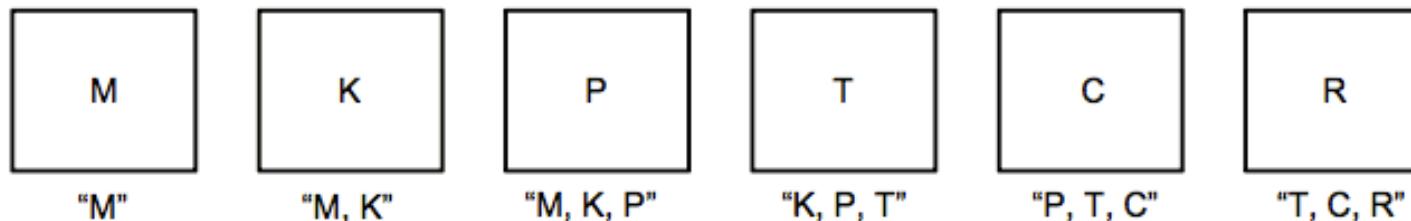
- How do I get into grad school?
  - Figuring out what I am interested in
  - Working in a lab to learn about research
  - Contacting professors to get recommendations
  - Looking at schools
  - Sending applications & taking tests on time
  - Going to interviews (Social skills, learning skills)
  - Making a decision about where to go
    - Listing pros and cons

# Why do we care?

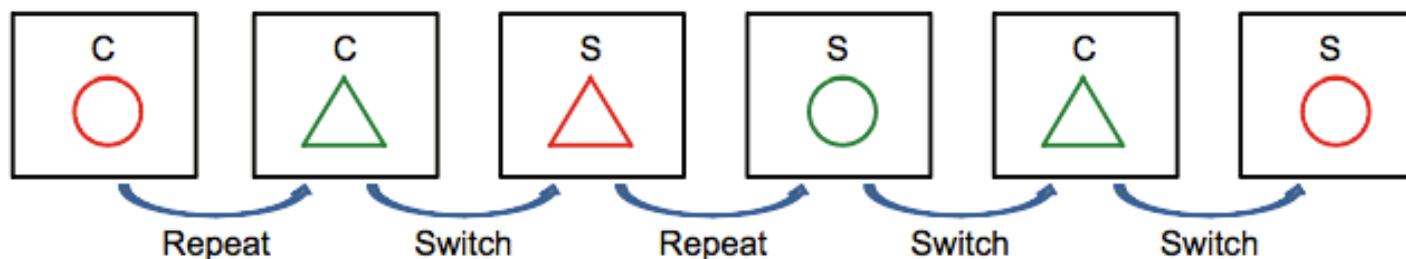
- Clinical disorders involve impairments in executive function
- Depression:
  - Enhanced focus on negative stimuli
- Addiction
  - Enhanced focus on & behavior to seek out addictive substance
  - Poor top-down control/inhibition of drug-seeking response
- OCD
  - Habit pathway – prepotent responses to distressing stimuli must be overcome with cognitive control
- Put your favorite disorder here – chances are it involves EF deficits (see Snyder, 2016)

# Examples of different EF tasks

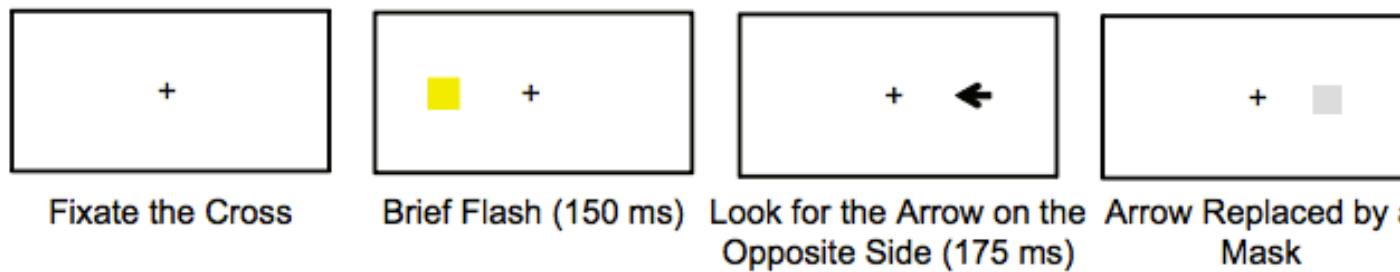
## Updating: Letter Memory Task (Always Remember the Last 3 Letters)



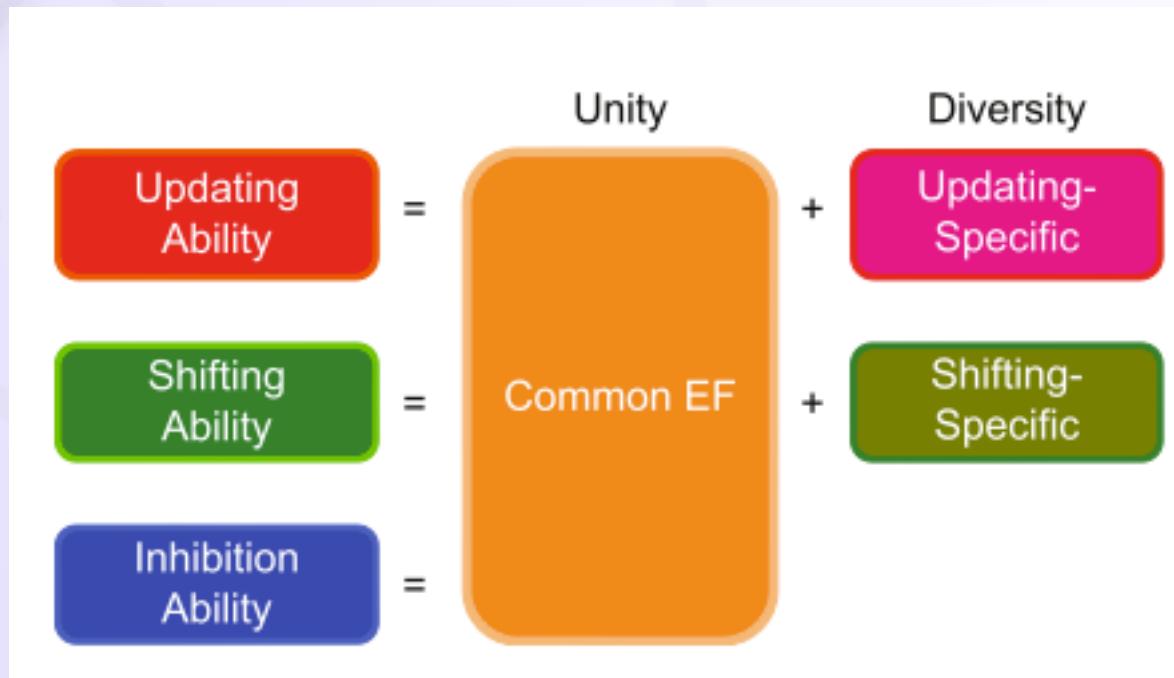
## Shifting: Color-Shape Task (Classify Each Target by Color [C] or by Shape [S])



## Inhibition: Antisaccade Task (Report the Arrow Direction Presented on the Nonflashed Side)

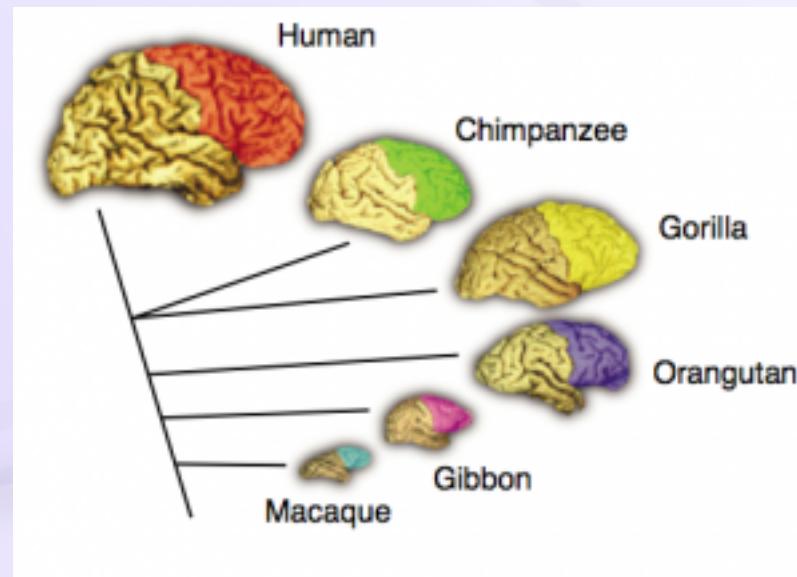
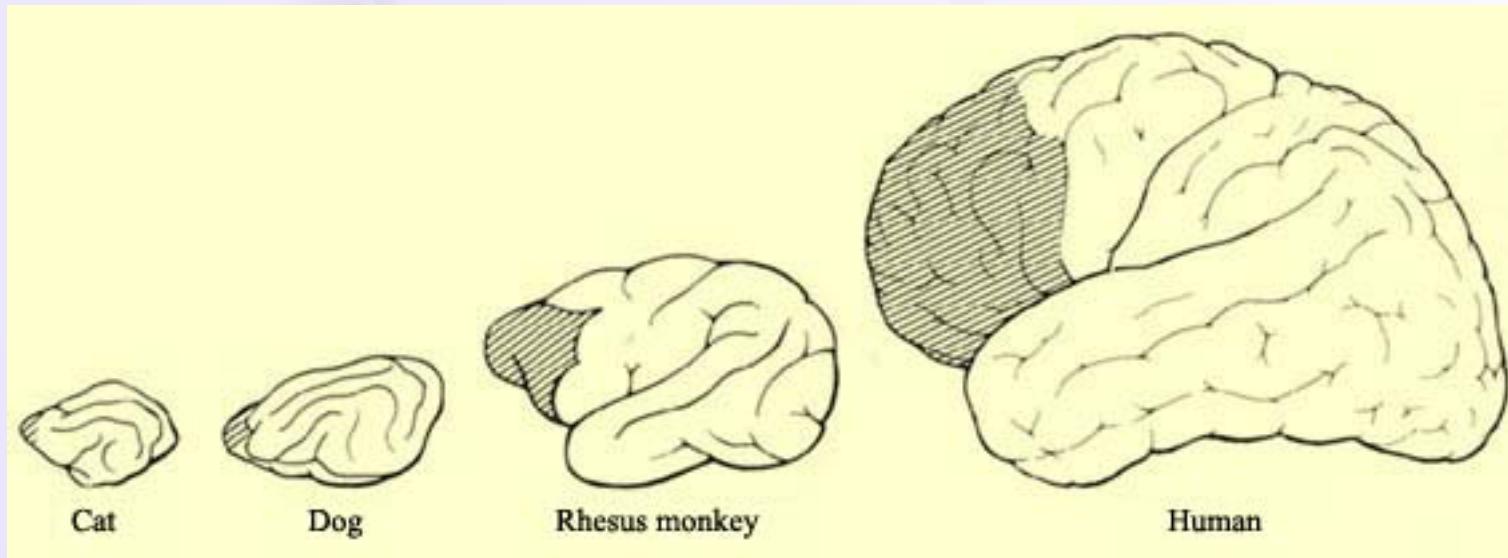


# Different parts of EF

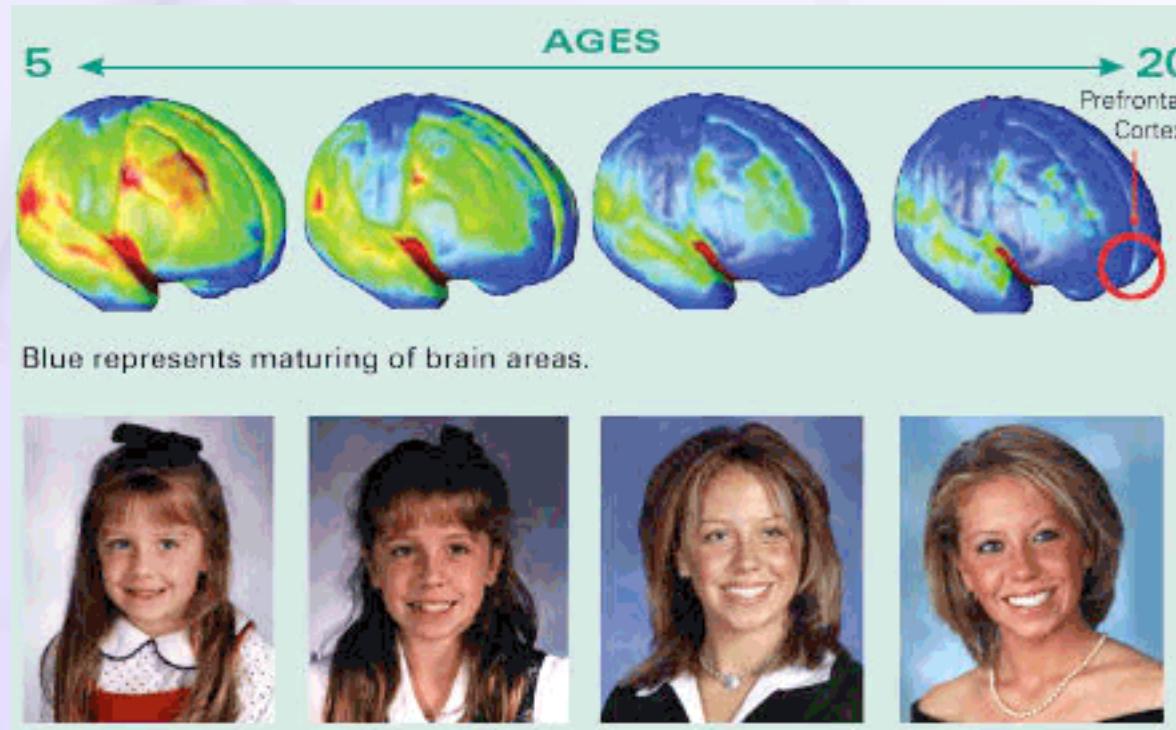


Friedman & Miyake, 2012

# Prefrontal cortex across species



# Prefrontal cortex across life



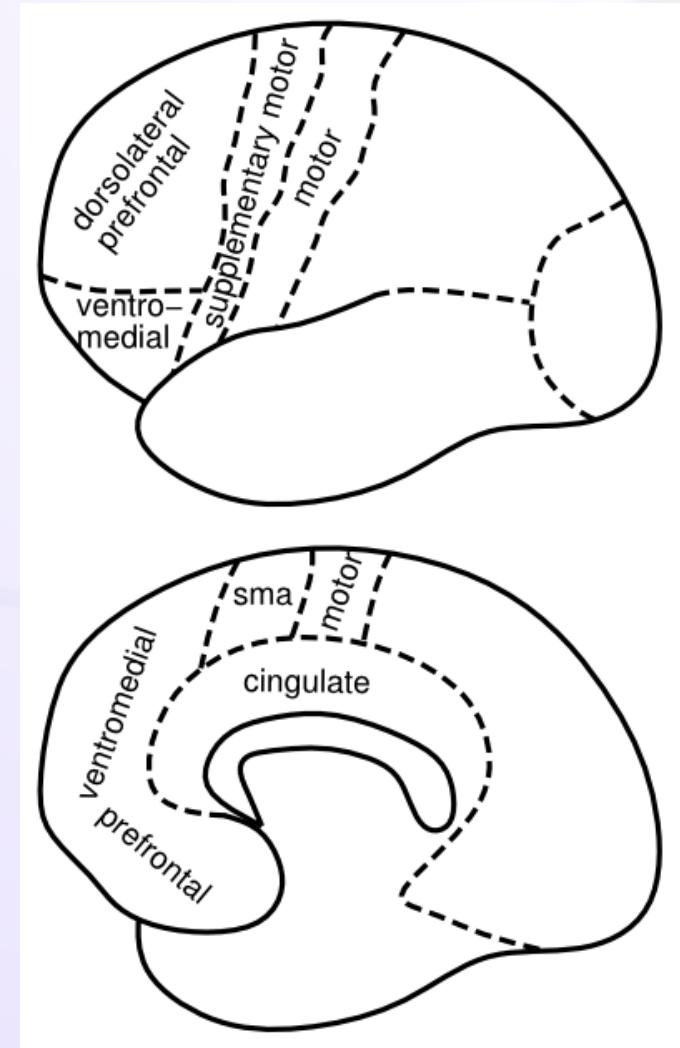
- Does this development of prefrontal cortex link to impairments in decision making you may see with adolescents?

# Who is in Charge of your Brain??

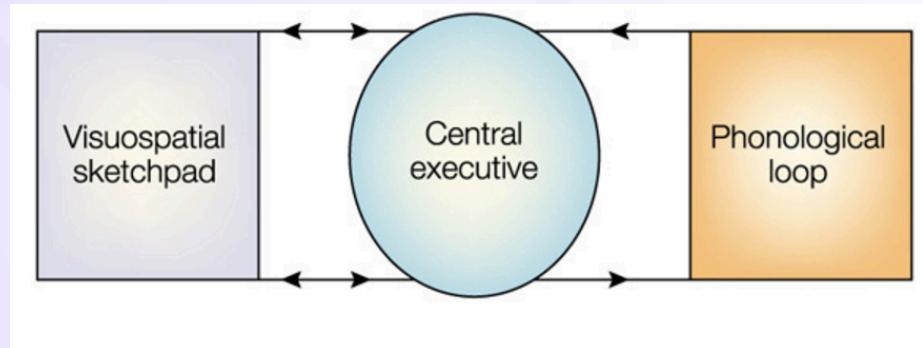
Prefrontal Cortex?

Integrates:

- Cognitive Control
- Planning
- Motivation
- Reward processing
- Decision making

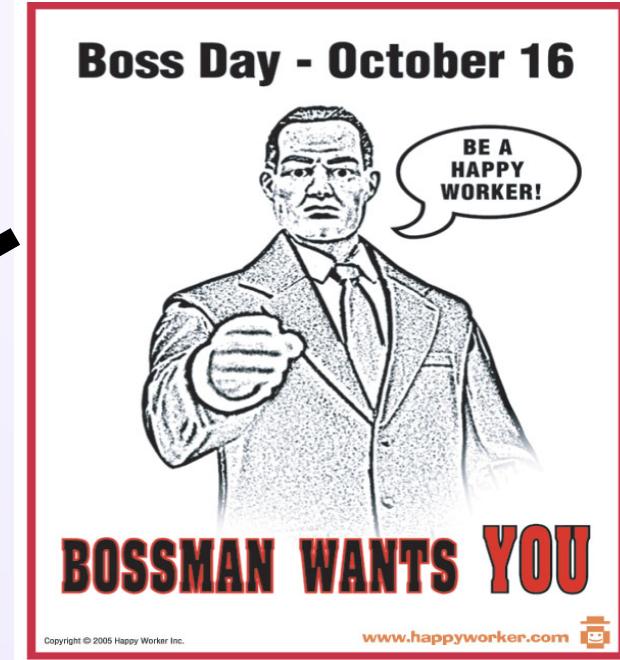
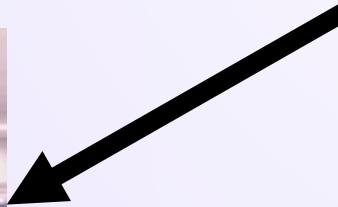


# Baddeley/Hitch model



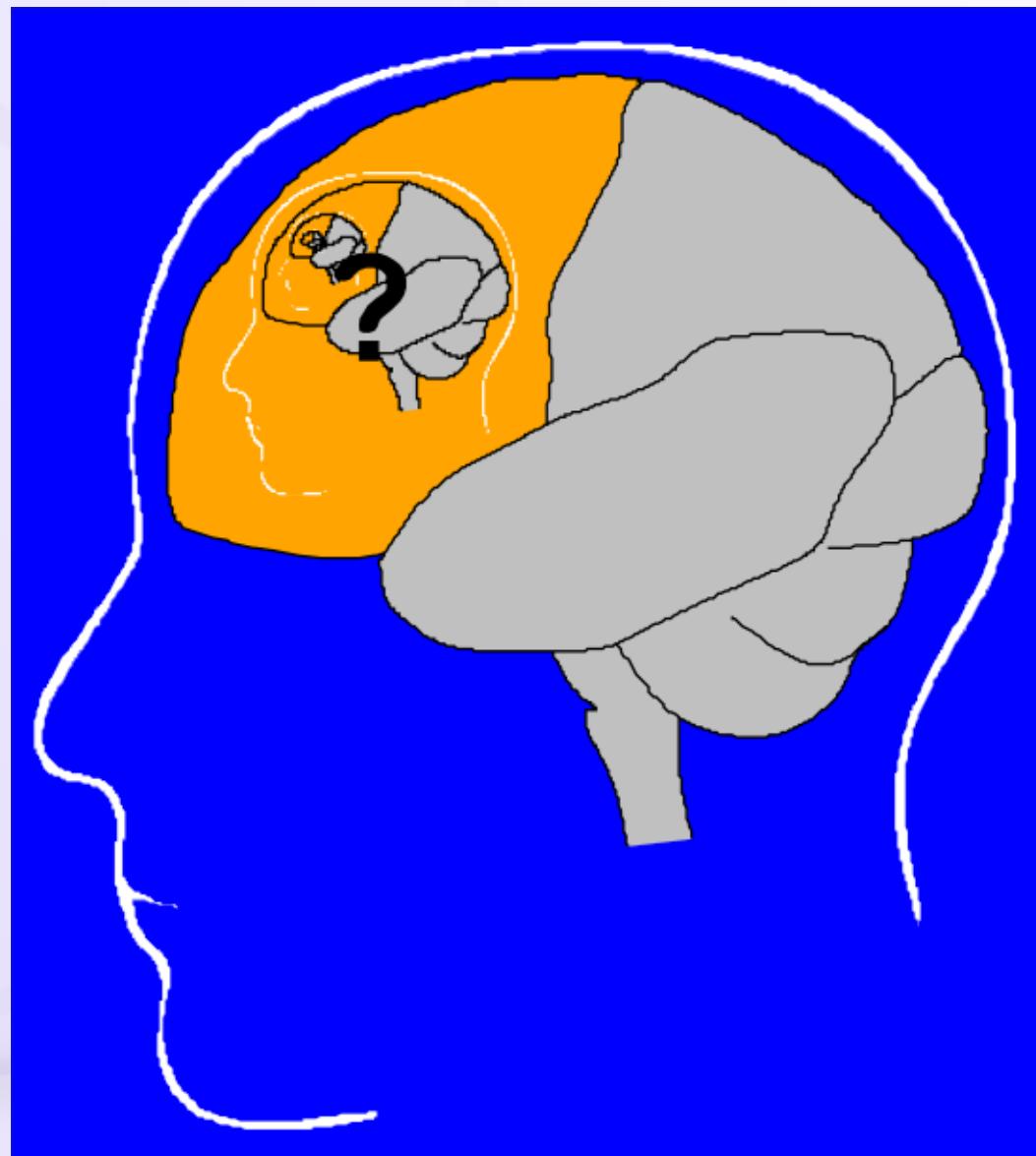
- Influential account of working memory
  - Phonological loop: Hold information for a few seconds, maintain through rehearsal
  - Central executive: Switch & focus attention
  - Visuospatial sketchpad: ongoing manipulation of visual/spatial items

# Key Idea: Top-Down Biasing

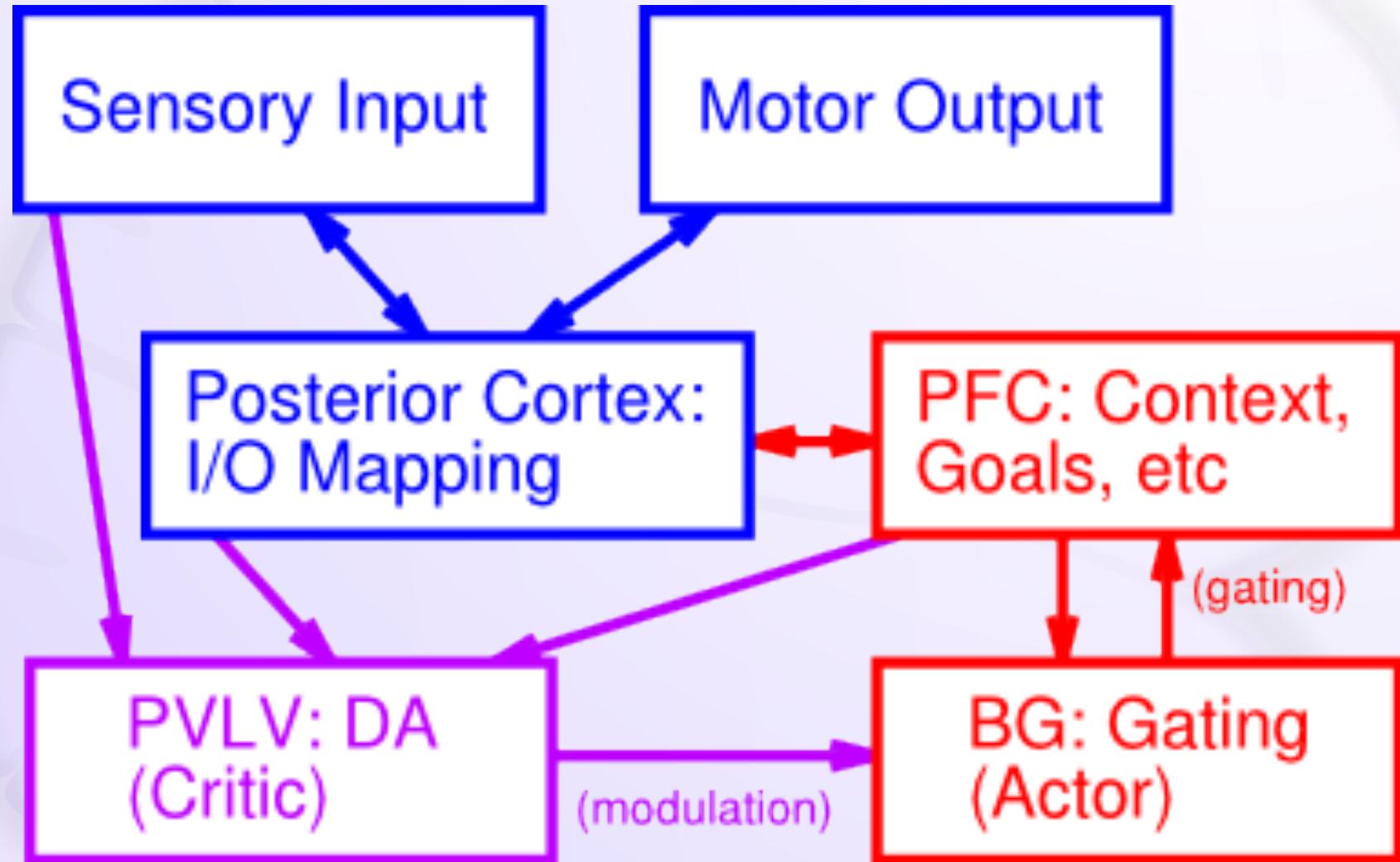


- PFC active maintenance provides top-down biasing of posterior-cortical processing

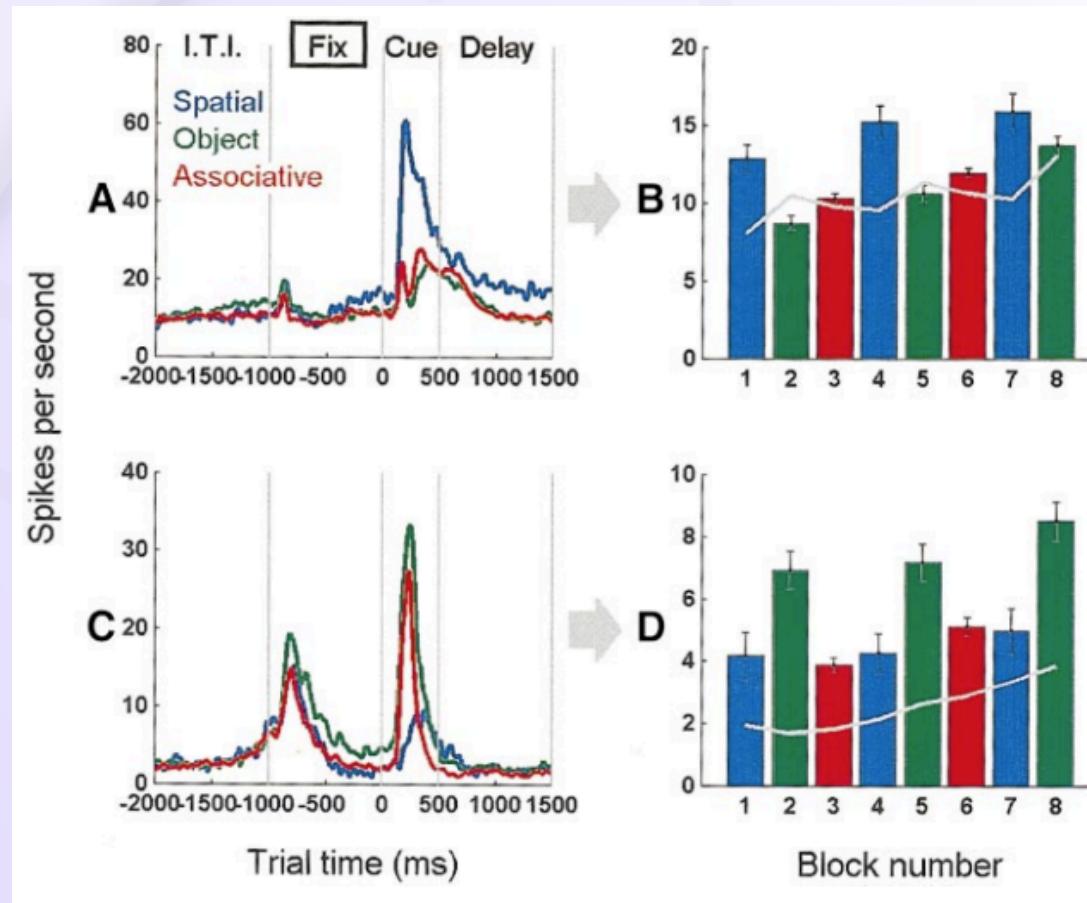
# The Homunculus Problem



# It Takes a Network..



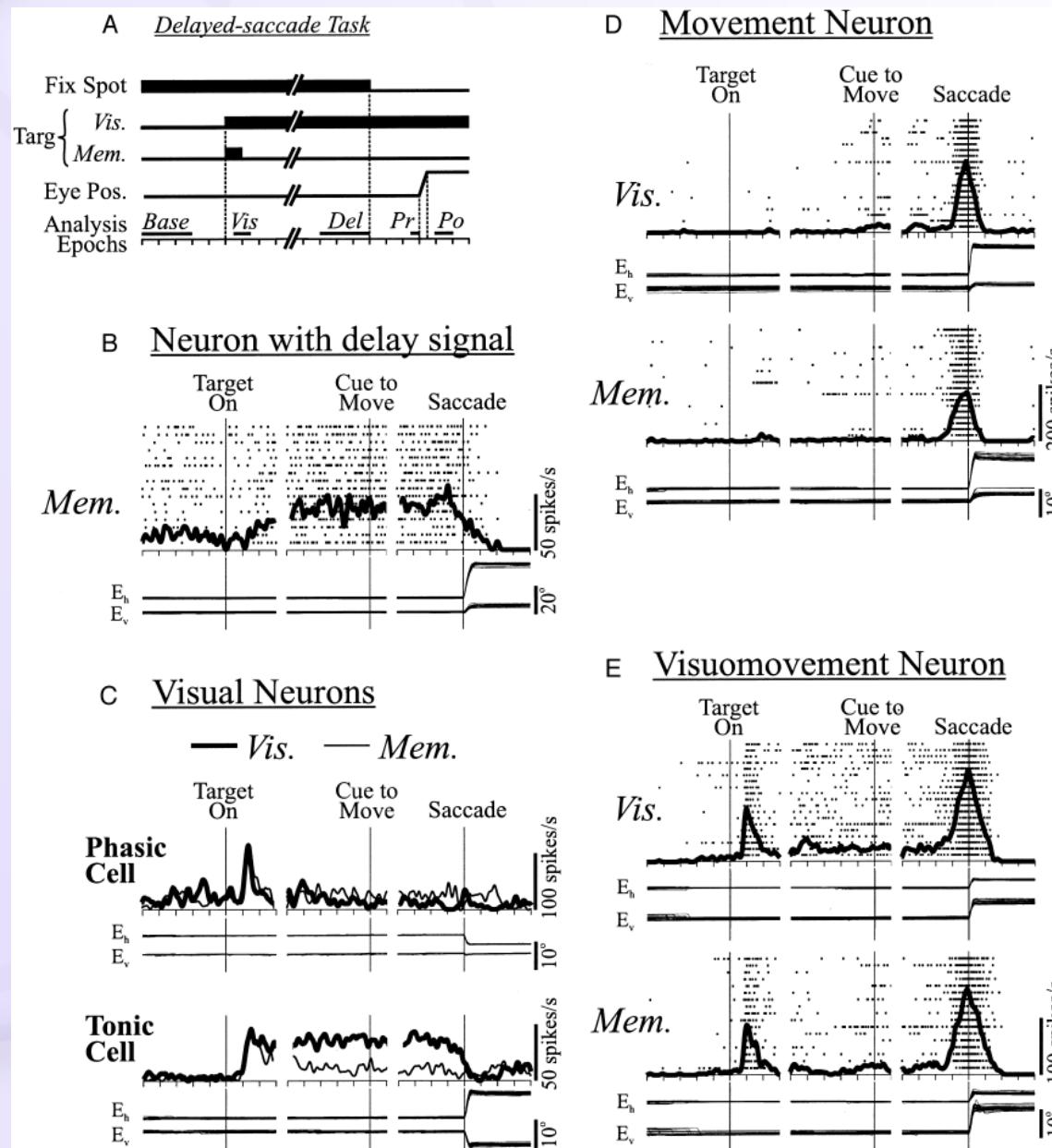
# What is the PFC maintaining?



Miller – 2000 - Monkey does several different tasks

During the delay period, you see differences in activity depending on the task, meaning that the PFC encodes “task” rules

# PFC Does Active Maintenance



# Active Maintenance Can Do it All

- Cognitive Control
  - Maintained activity drives top-down biasing
- Planning
  - Think about things that are not there (future)
- Motivation
  - Maintain goals
- Reward processing
  - Maintain possible outcomes
- Decision making
  - Maintain alternatives

# The Need for Robust Maintenance

- "Every sound has to be an earthquake or tidal wave that topples governments and changes national boundaries and mutates whole species so they suddenly drift off the planet, across galaxies, only to return, years later, when nobody wants to know them cause their credit rating's bad or because they can't do the Mashed Potatoes." - MFU by HC, 1998
- Subjective experience of PFC lesion: dreaming!

# Stroop Task: Top Down Biasing

RED

# Stroop Task: Top Down Biasing

GREEN

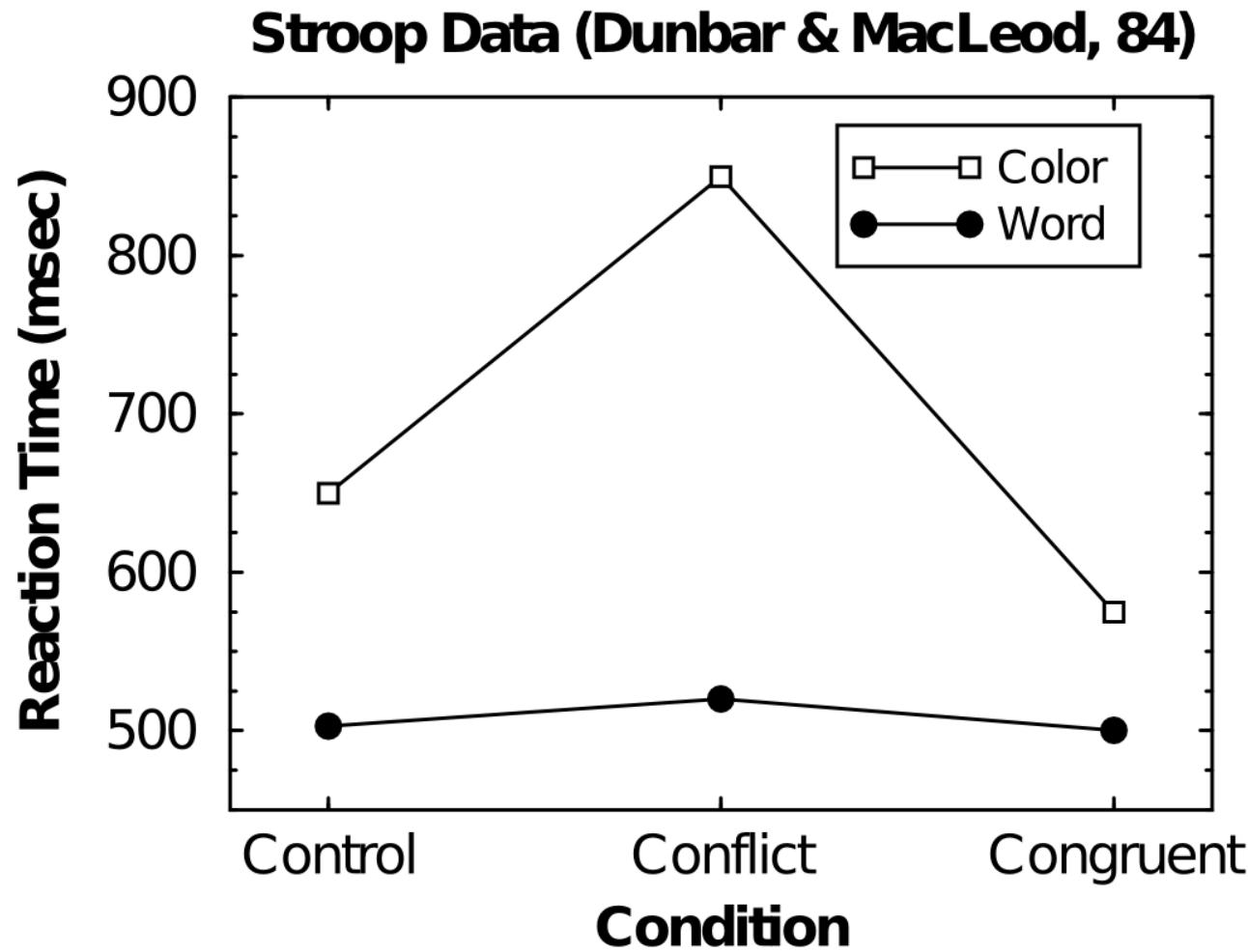
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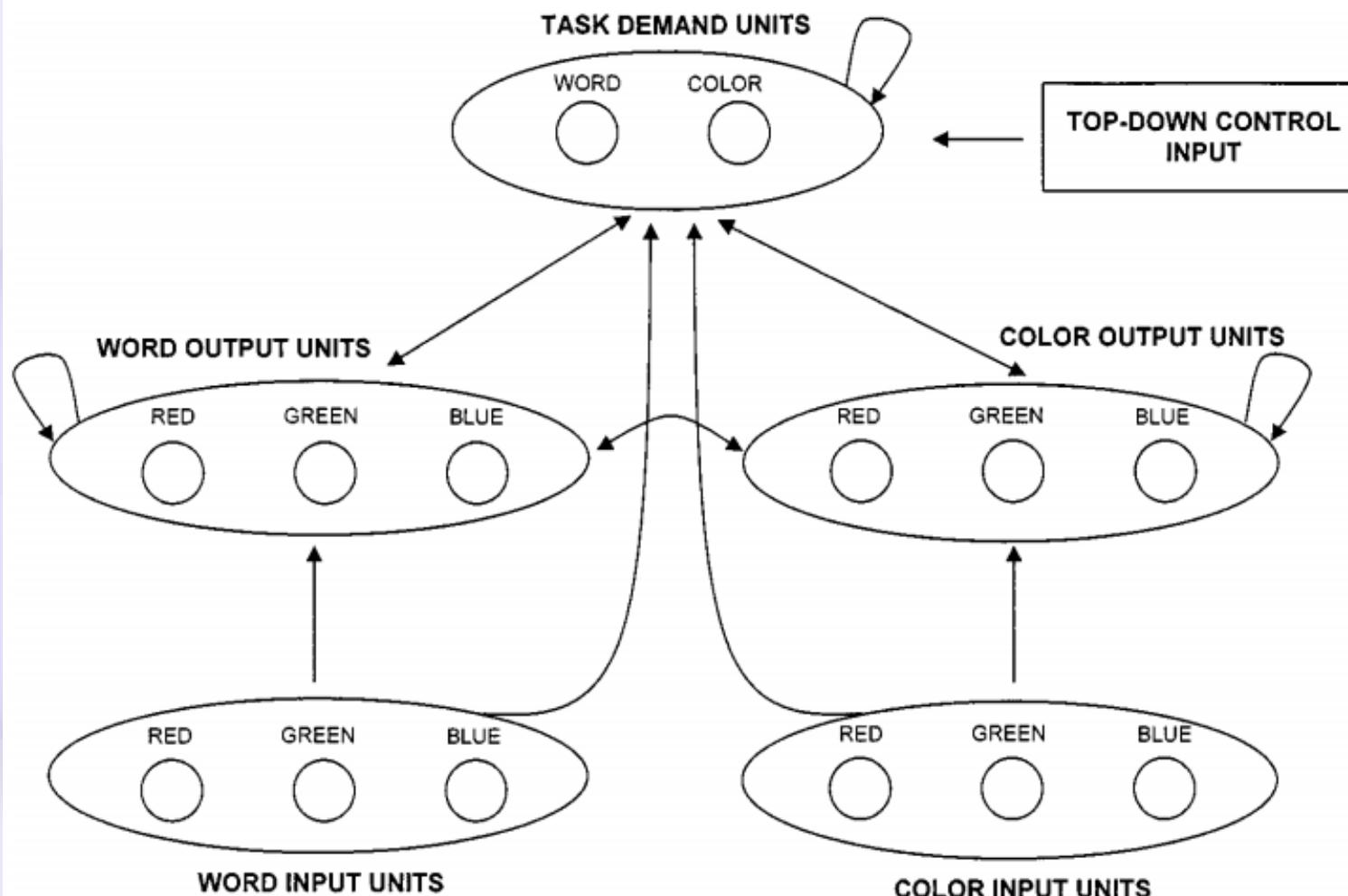
# Asymmetric Conflict



# Model of the Stroop task

A PDP MODEL OF TASK SWITCHING

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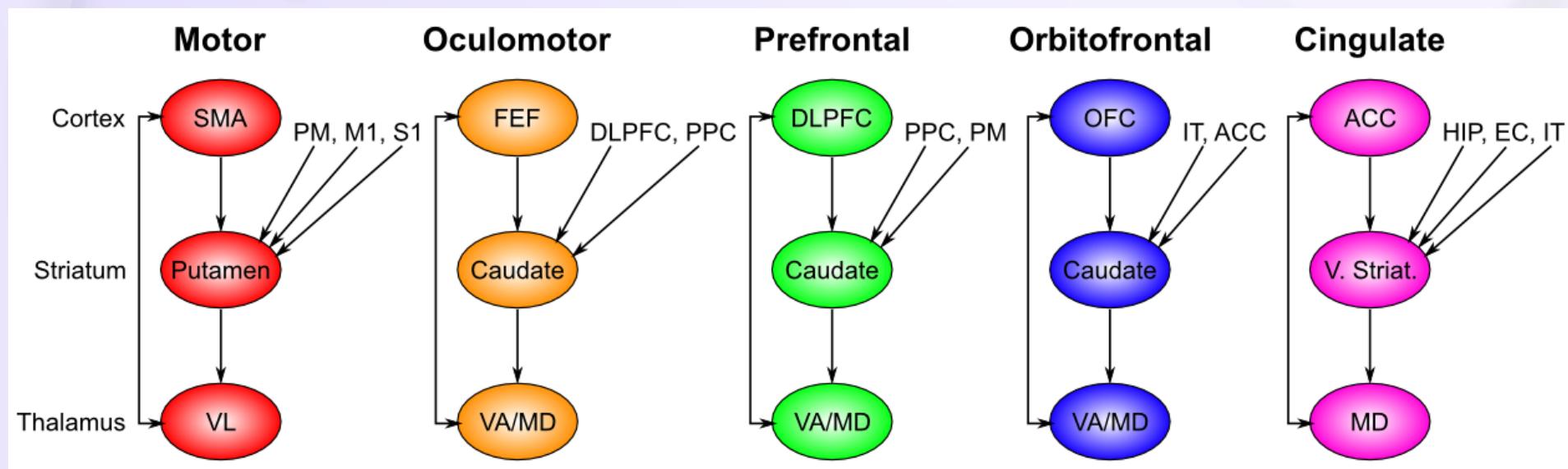
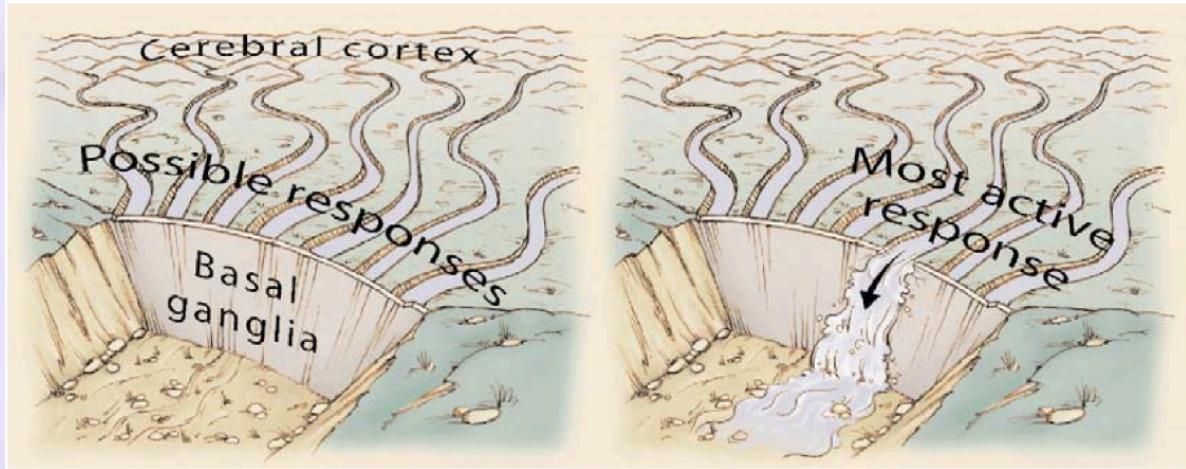


**FIG. 2.** Architecture of the present model.

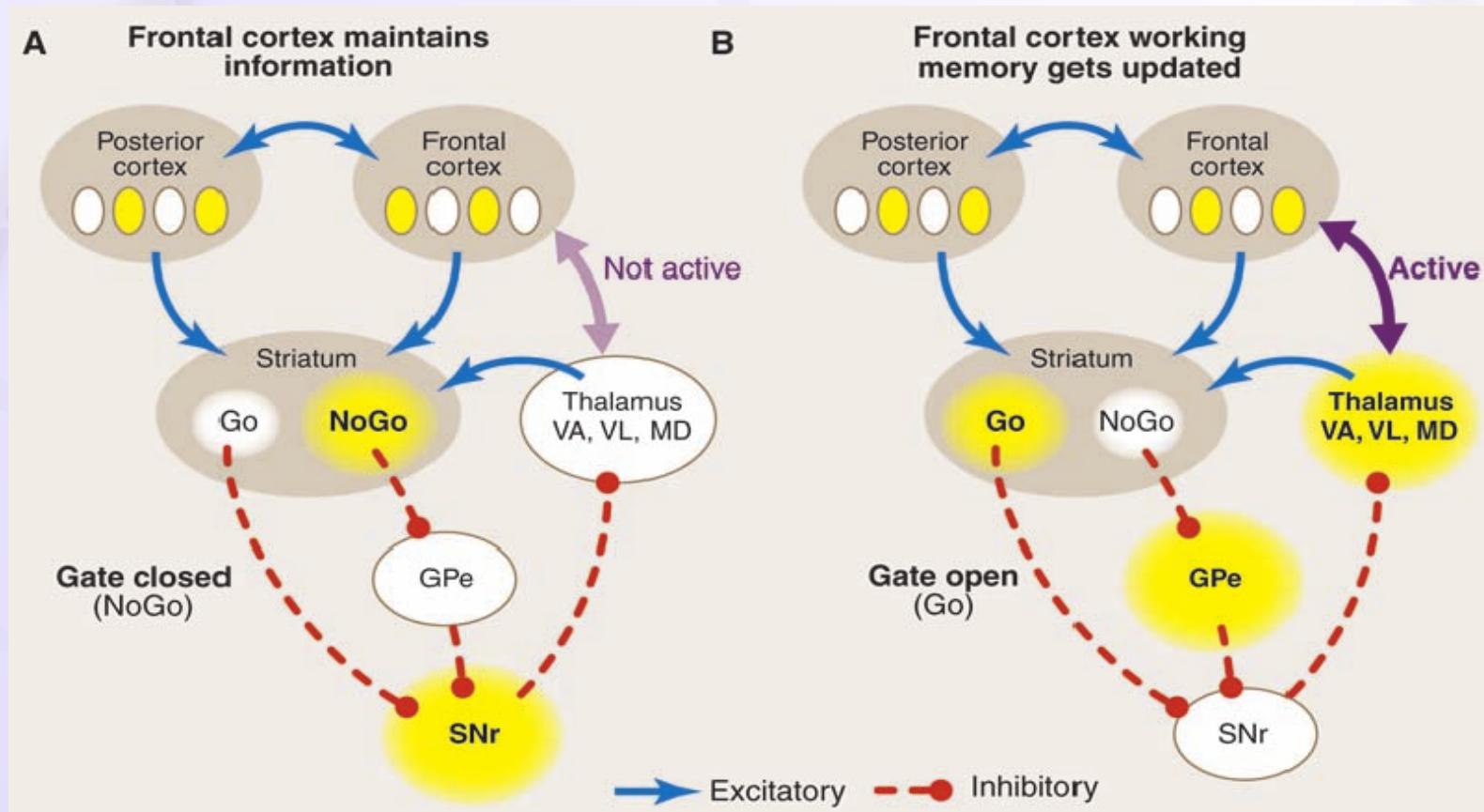
# Robust Active Maintenance

- In Stroop model, we just clamp PFC units on..
- What makes them “clamped” in the real brain?
  - How do the PFC units show sustained activity?
- BG!

# Motor Gating => Cognitive Gating

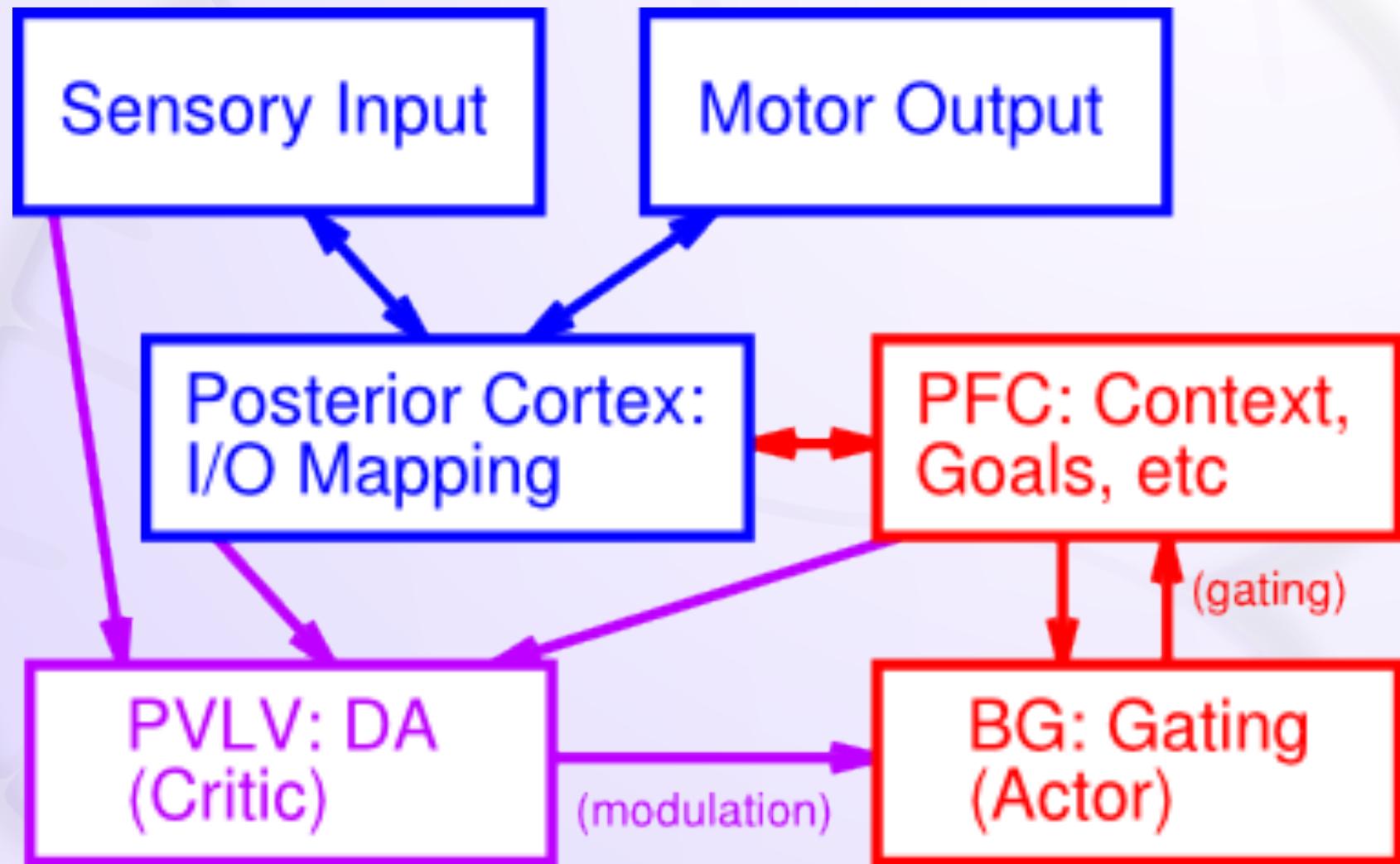


# Dynamic, Adaptive Gating (BG)

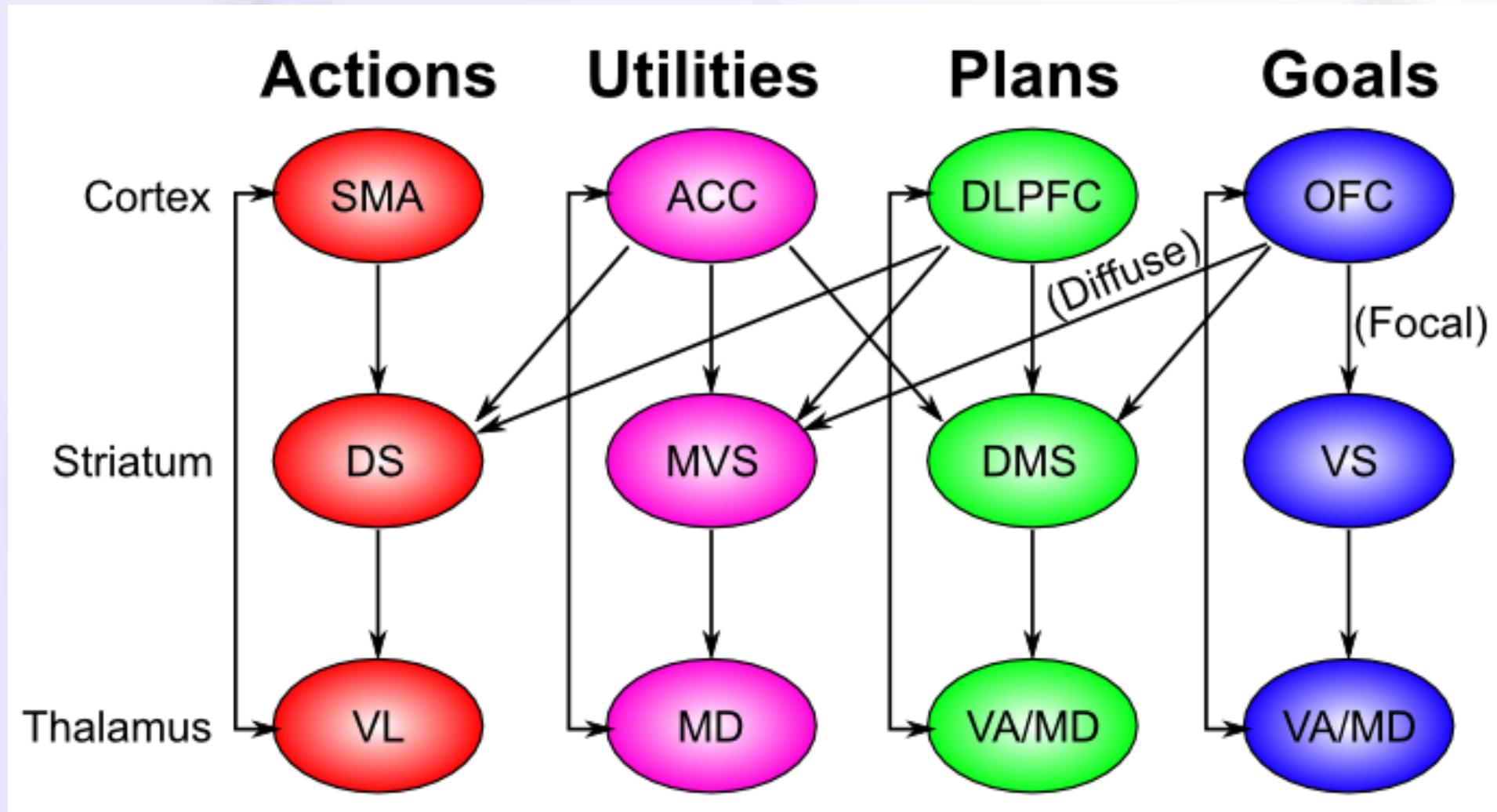


- Toggles PFC bistable states
- Resembles transistor logic gate!

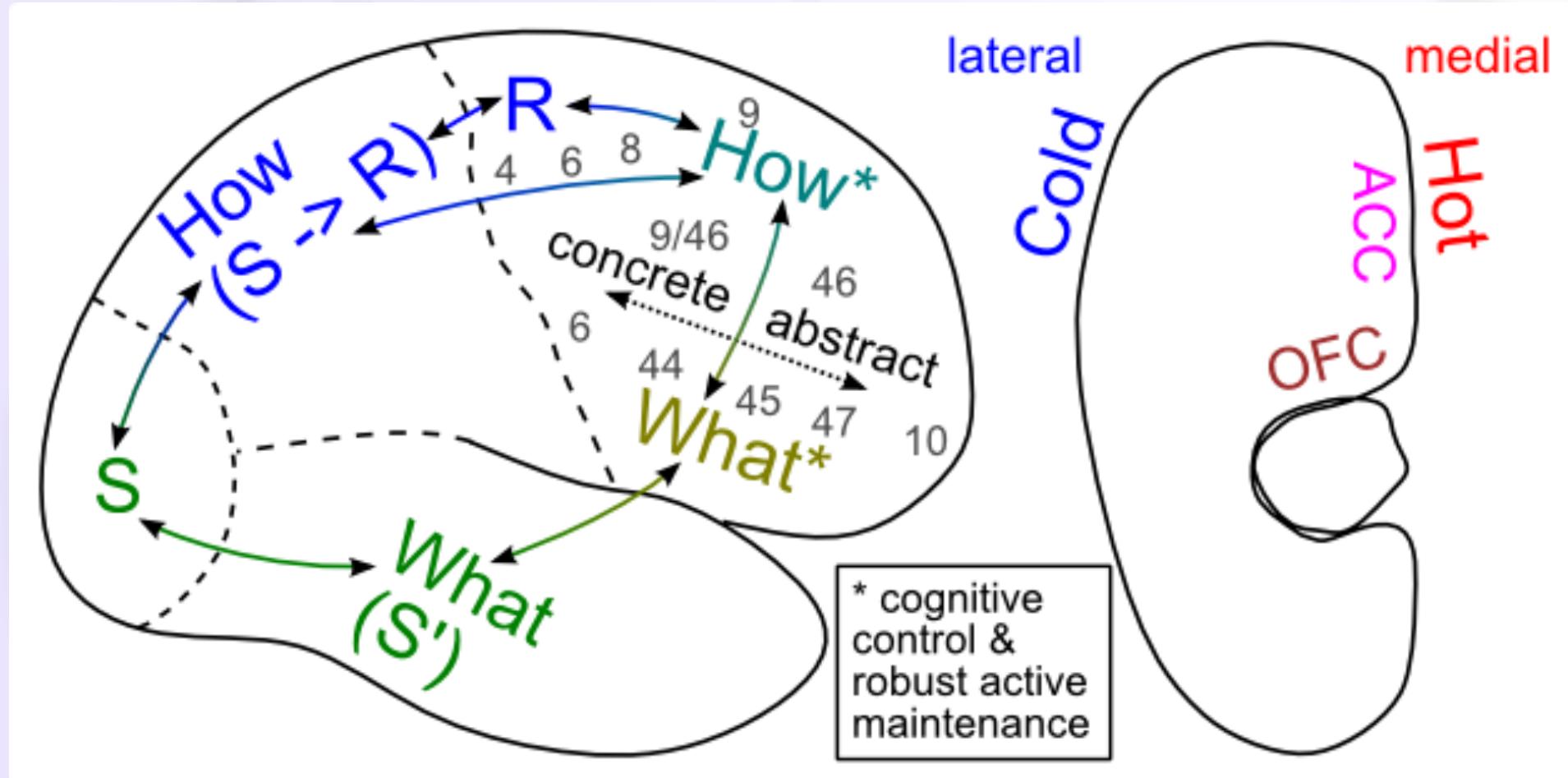
# PBWM System (O'Reilly, Frank 06)

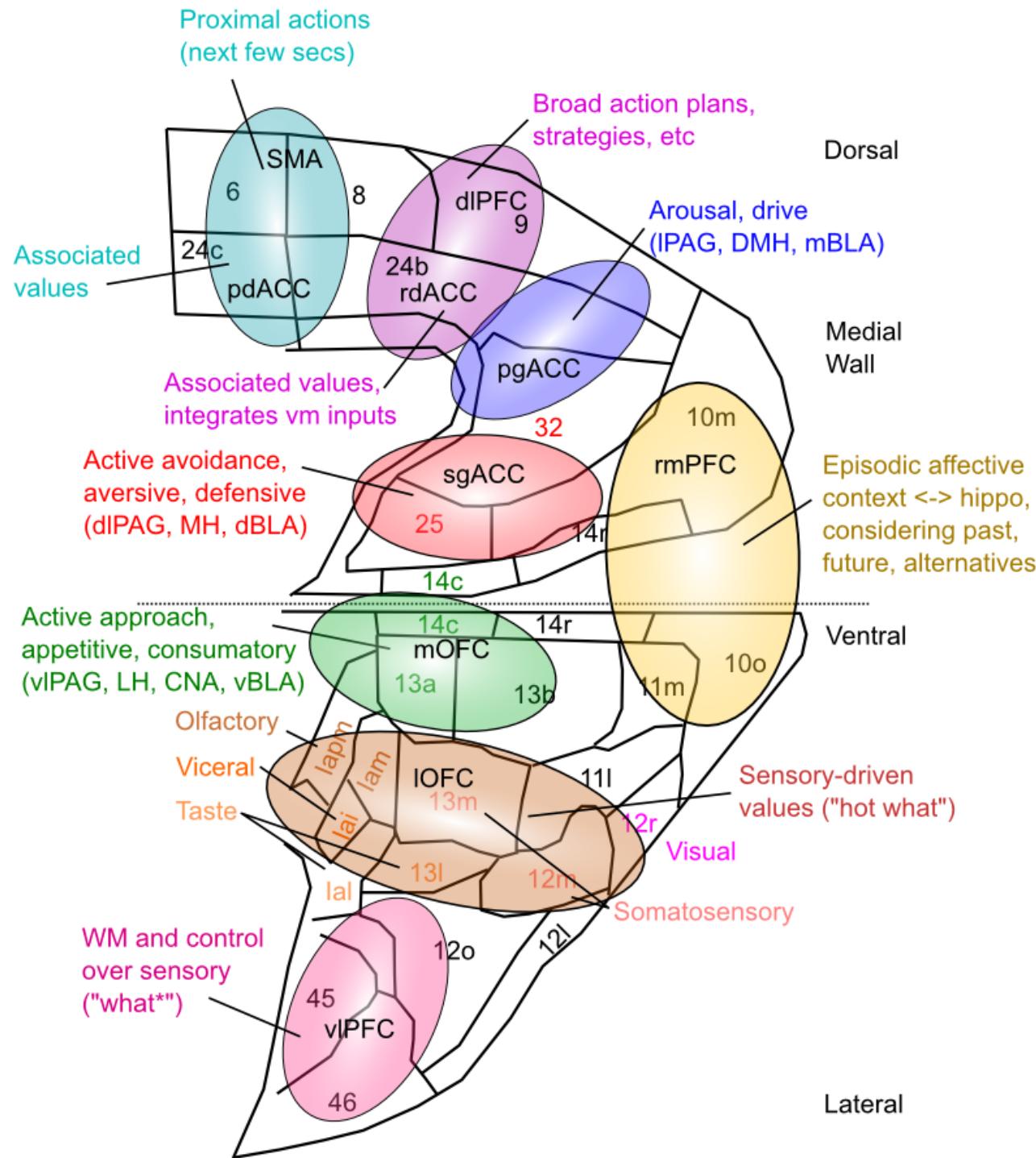


# Chain of Command..



# Executive Function





# Medial Frontal Map of Values

This is your emotional life

# Biological Basis of PBWM

