

Cognitive Control



Announcements

Midterm 1

- Tuesday, April 19th @ 9am**
- Location: Braun Auditorium**

Review Session

- Sunday, April 17th @ 5pm**
- Location: 420-041**
- Come prepared with questions
- Use Piazza to pose questions to the TAs btw now and the midterm review

T F Sperling's *partial report* procedure demonstrated that although attentional capacity, or information-processing capacity, is limited, visual sensory memory seems to contain all presented visual input.

As discussed in the textbook, in the Wisconsin Card sorting task, individuals with frontal lobe damage:

- a. Are unable to learn any rules by which to sort the cards.
- b. Are unable to shift to a new rule once an old rule becomes irrelevant.
- c. Are unable to keep track of how they sorted the cards on previous trials.
- d. A and C

Define the *primacy effect*

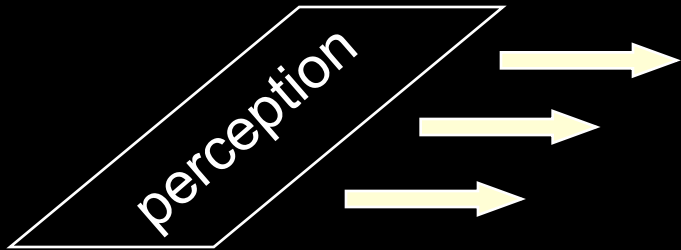
Describe the *Systems Hypothesis* and the *Emergent Hypothesis* of working memory, and state the main difference between these two accounts. In your answer, please discuss how each account conceives of the role of neural representations of perceptual information in working memory.

Outline

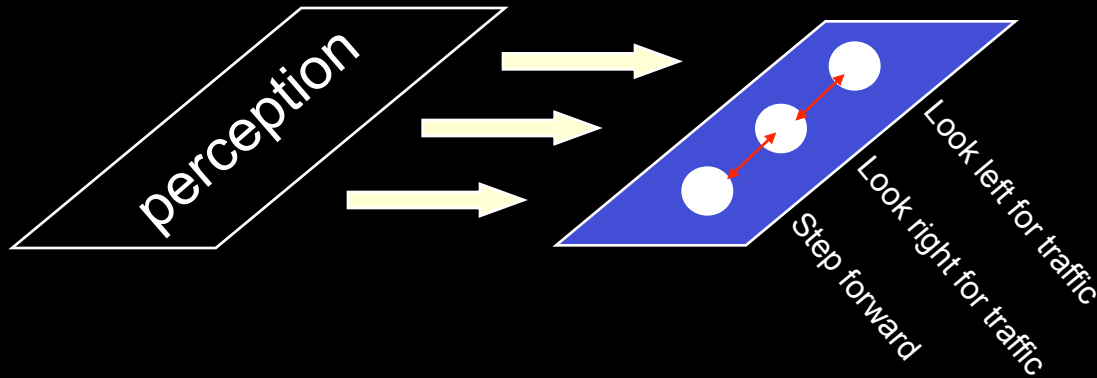
- Goal-directed (controlled) vs. Automatic Action
- What is Cognitive Control?
- Prefrontal Cortex and Cognitive Control
- Single vs. Multi-Process Theories of Control
- What Regulates Cognitive Control?



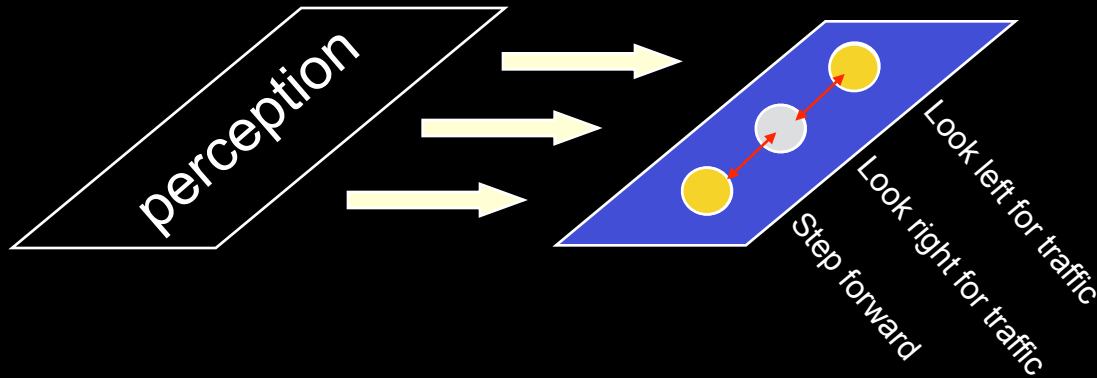
The Need for Cognitive Control: Crossing the Street in the U.K.



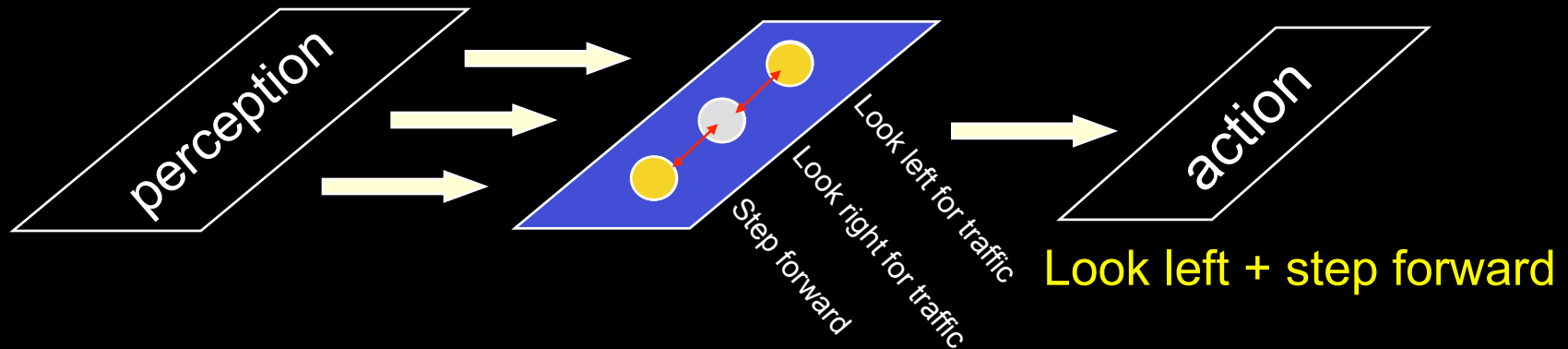
The Need for Cognitive Control: Crossing the Street in the U.K.



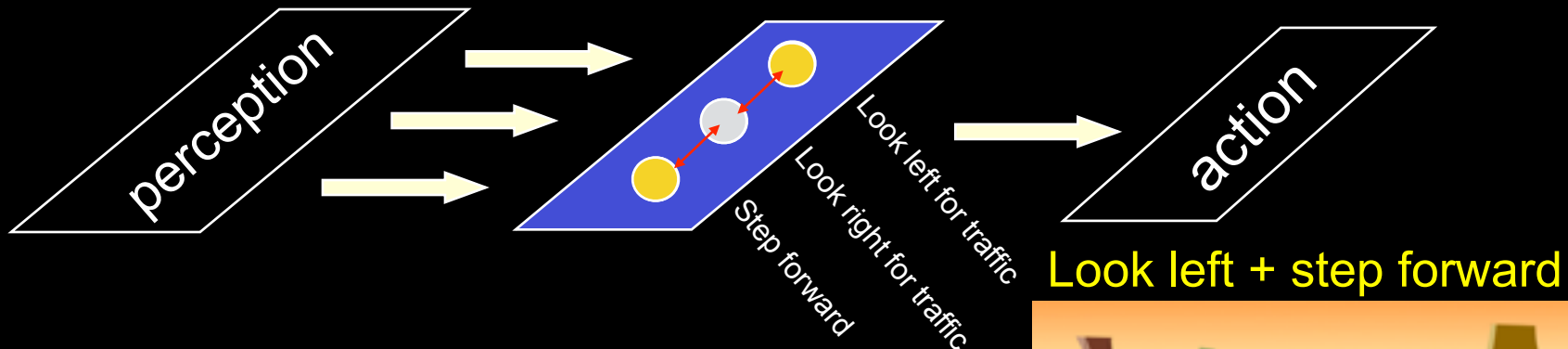
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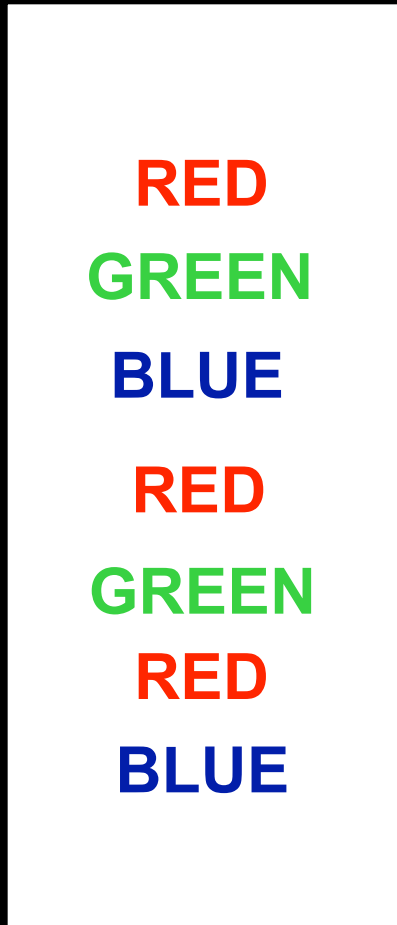


Automatic behavior is inappropriate given the current context / set of rules



The Need for Cognitive Control: The Stroop Effect

Name the color of the print



(Stroop, 1935)

The Need for Cognitive Control: The Stroop Effect

Name the color of the print

RED
GREEN
BLUE

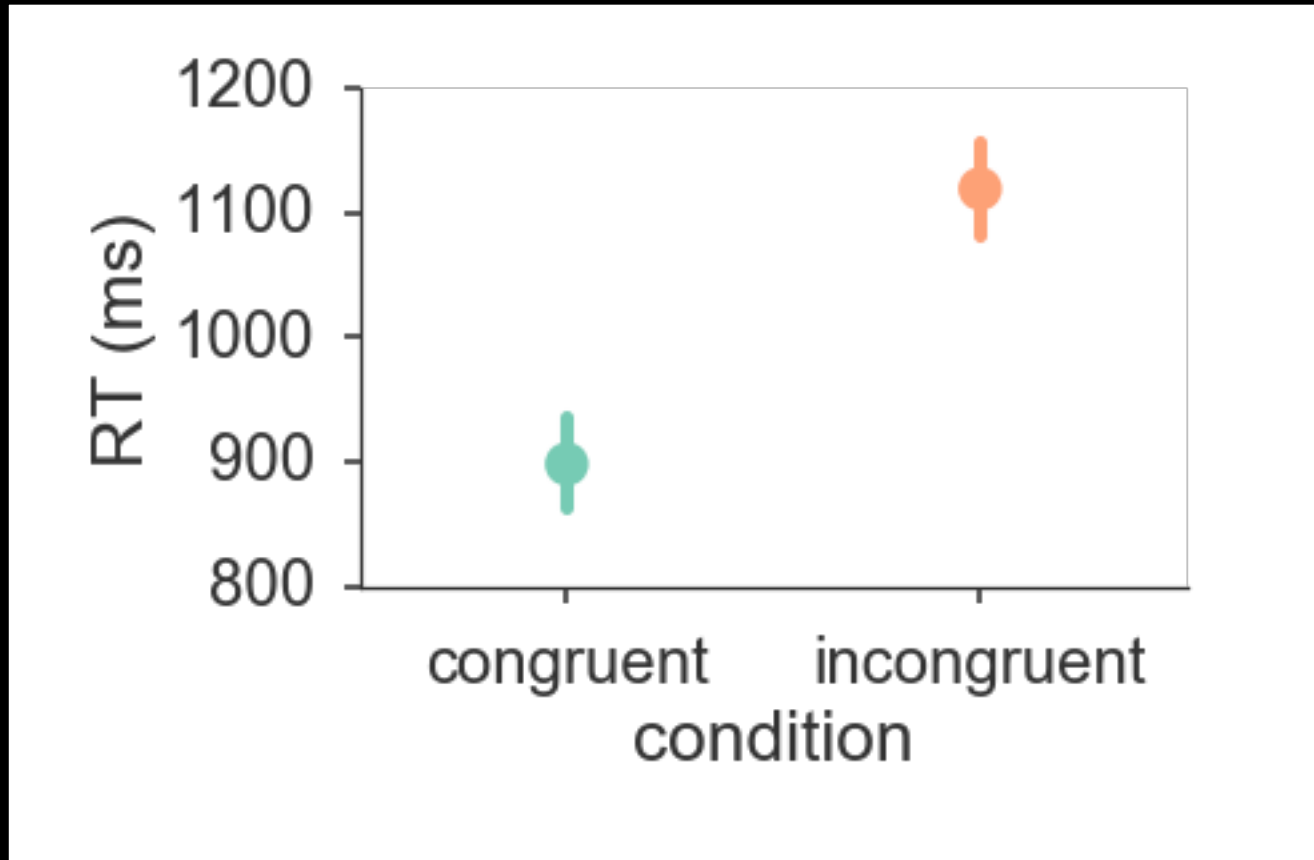
RED
GREEN
RED
BLUE

RED
GREEN
RED

BLUE
GREEN
RED
BLUE

(Stroop, 1935)

The Need for Cognitive Control: The Stroop Effect in Psych 45



Automatic behavior is inappropriate given the current task goal / rules

Other Real-World 'Stroop Effects'

- in a country that drives on the left side of the road. crossing the street.
- mobile apps not well designed: 'go' button colored red
- saying 'excuse me' in English in a country that speaks a different language, even when know the term in the other language
- taking a regular driving route when goal requires a novel route
- introductory improvisational theater, and in creating stories and scenes we have to practice naming things that aren't really there and imagining them. One exercise we do in the class is having students walk around the room, pointing at objects and boldly saying what they are: "Backpack! Ceiling fan! Wall!" Then we practice going around and pointing at objects and saying anything except what they are: "Backpack!" (to the floor), "trombone!" (to the window), "Edgar Allan Poe!" (to a water bottle). It's extremely difficult to do. Even though the task seems fairly easy based on its description, the act of looking at and pointing at an object makes it easy to err and call it what it actually is.

Supervisory Attentional System

(Norman & Shallice, 1980)

- Two forms of processing: automatic & controlled (willed) action



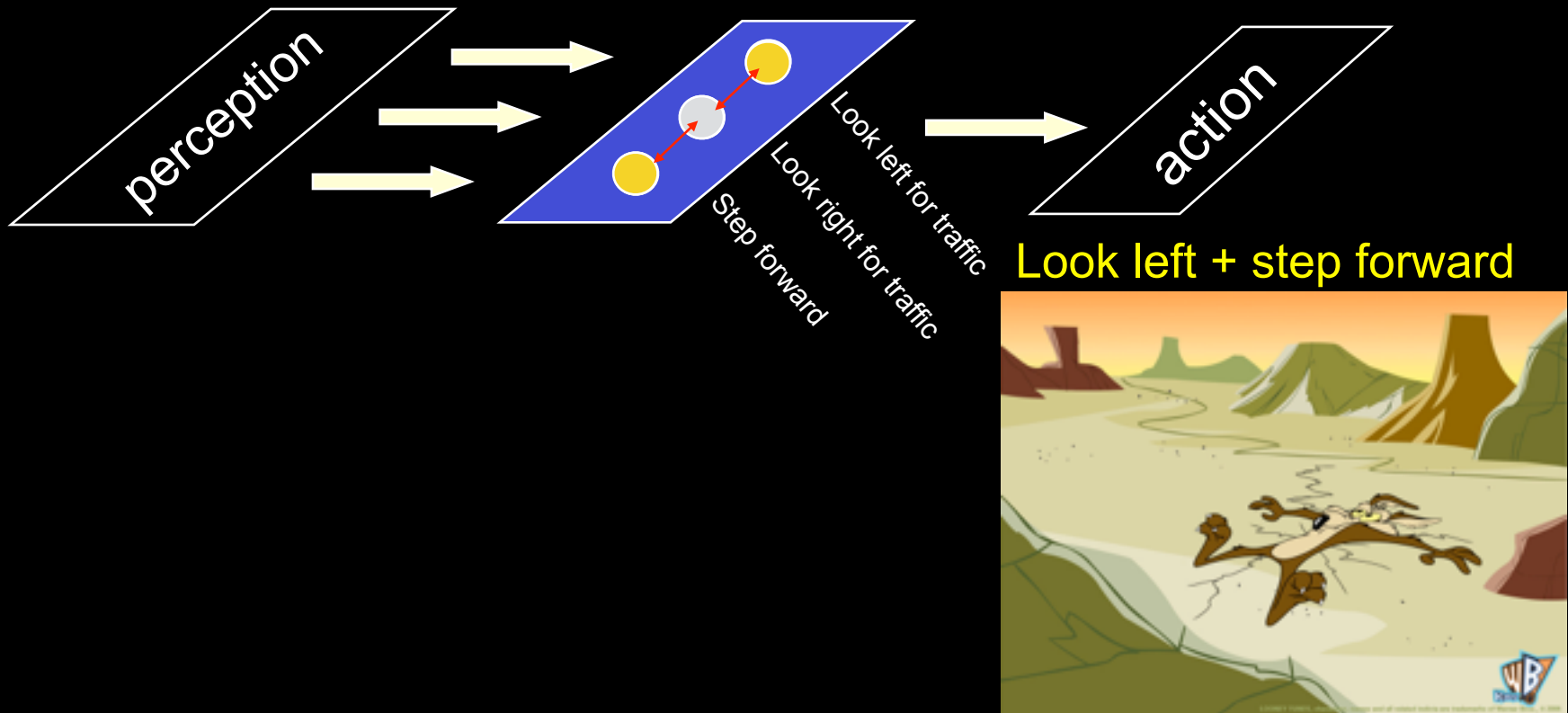
- **Automatic action**
 - triggered by stimuli and situational cues (e.g., Stimulus-Response Habits)
 - by convention: automatic processes do not interfere with other concurrent activities

Supervisory Attentional System

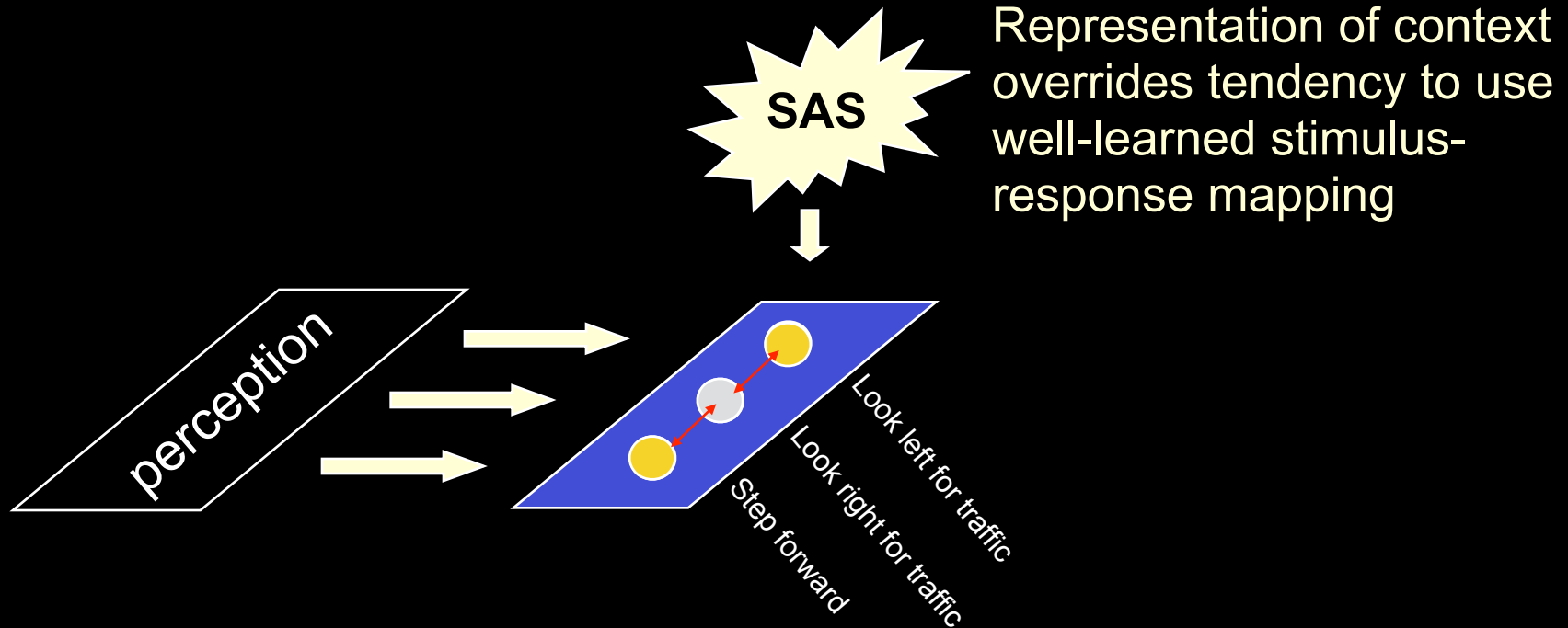
(Norman & Shallice, 1980)

- Two forms of processing: automatic & controlled (willed) action
- ❖ **Controlled action – SAS / Cognitive Control**
 - modifies behavior when automatic responses are inappropriate
 - inhibits automatic routines in favor of more appropriate behavior
 - biases the prioritization of cues

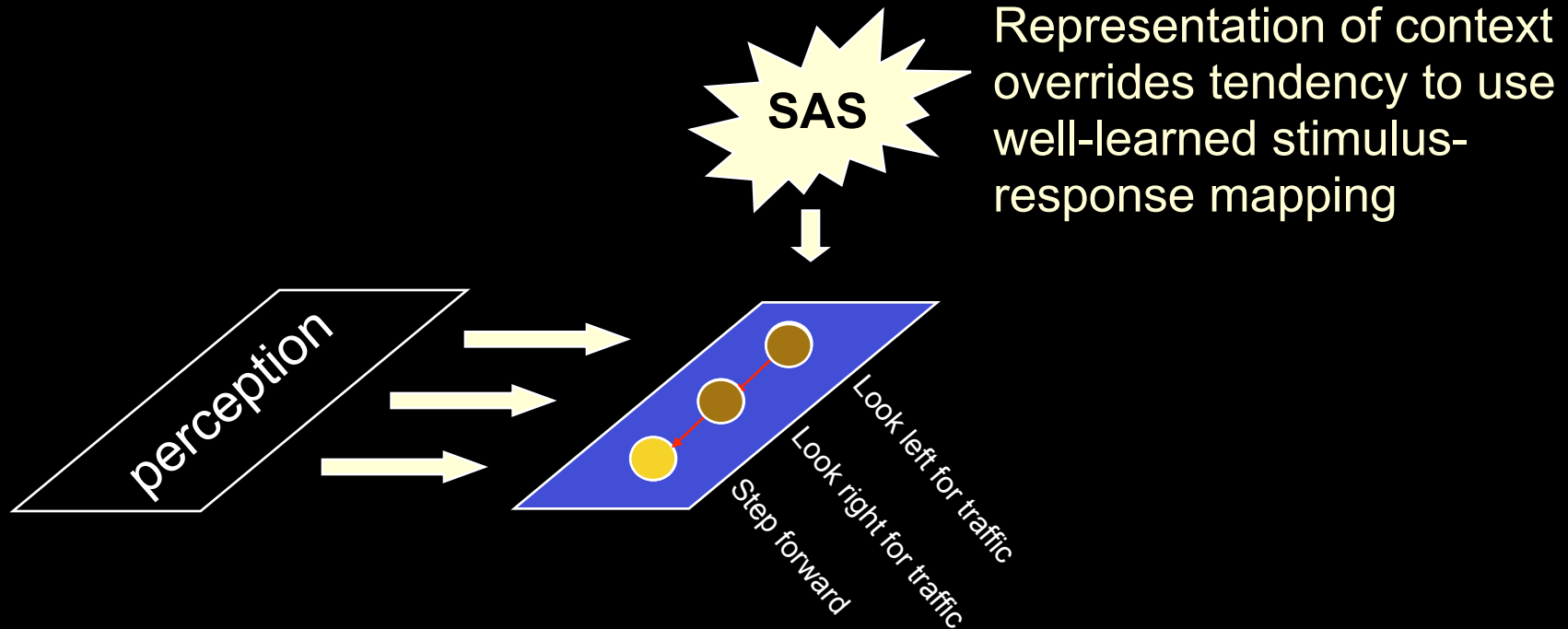
Supervisory Attentional System: Crossing the Street in the U.K.



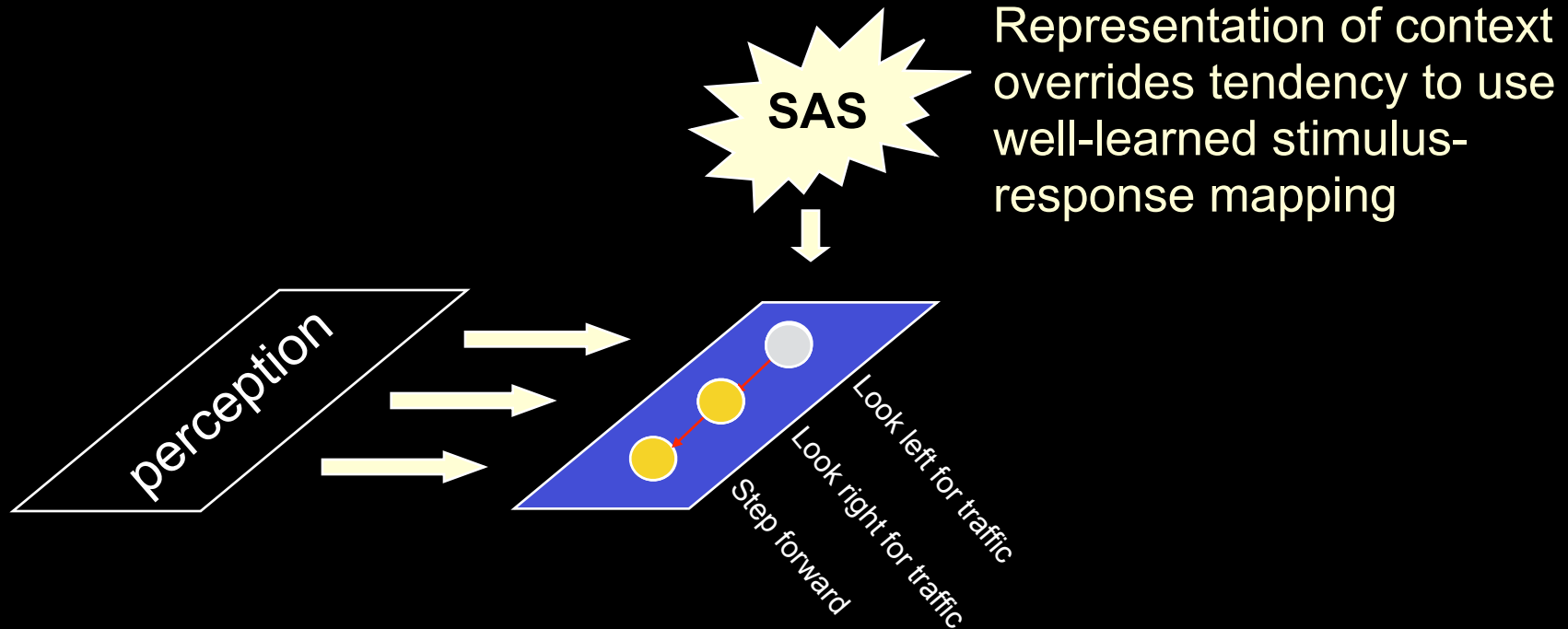
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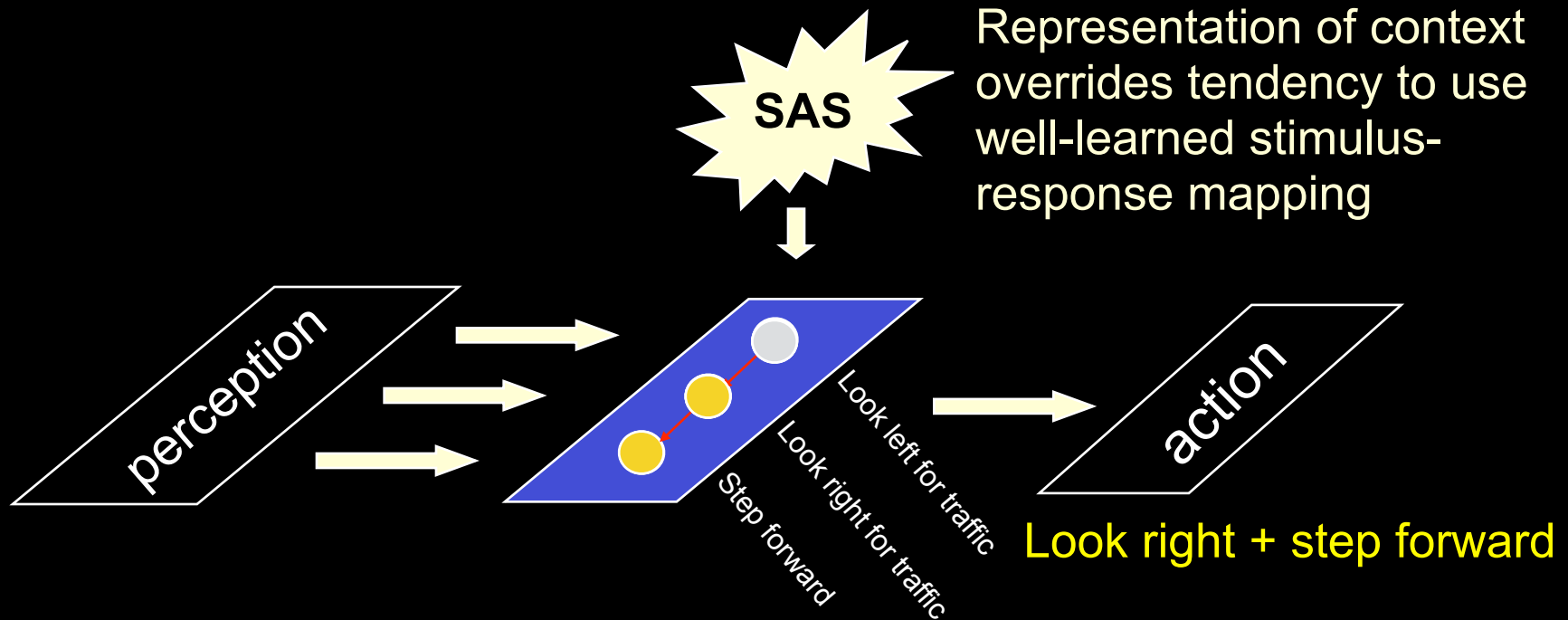
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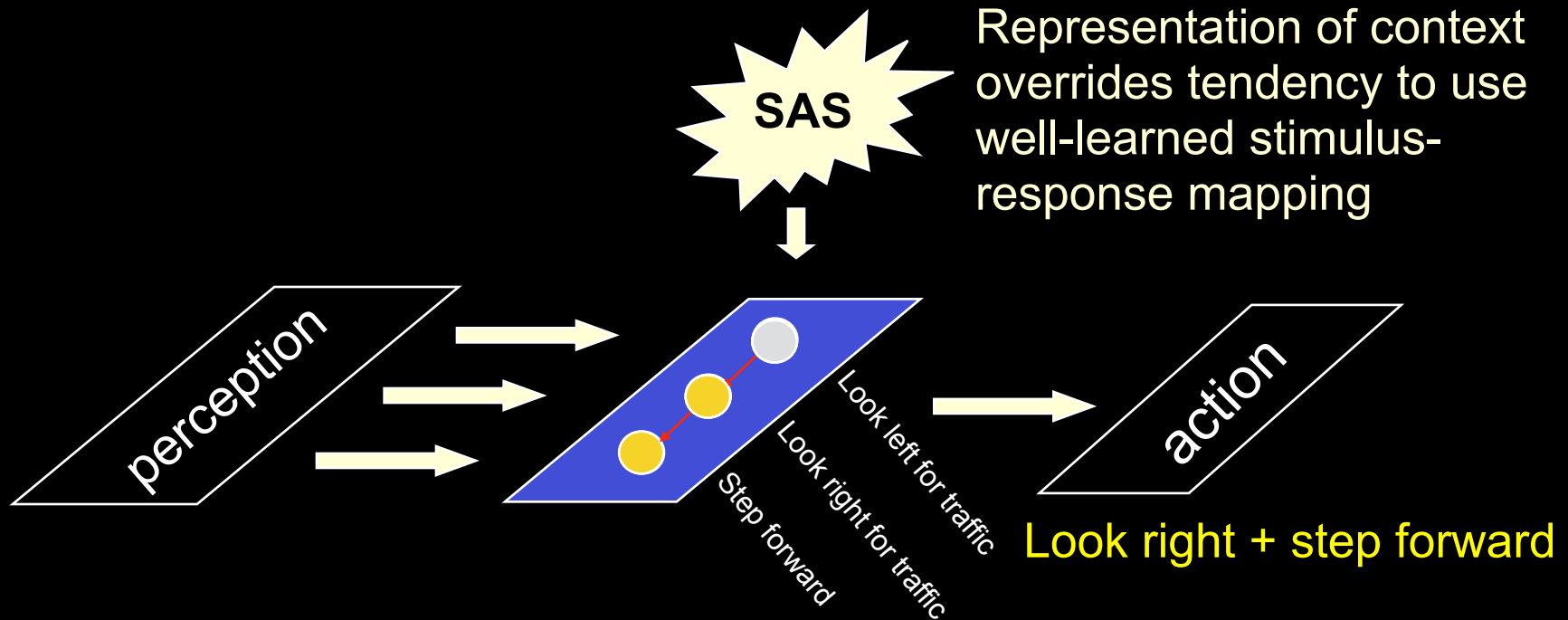
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Supervisory Attentional System: Crossing the Street in the U.K.



Outline

- Goal-directed (controlled) vs. Automatic Action
- **What is Cognitive Control?**
- Prefrontal Cortex and Cognitive Control
- Single vs. Multi-Process Theories of Control
- What Regulates Cognitive Control?



Cognitive Control / Executive Function

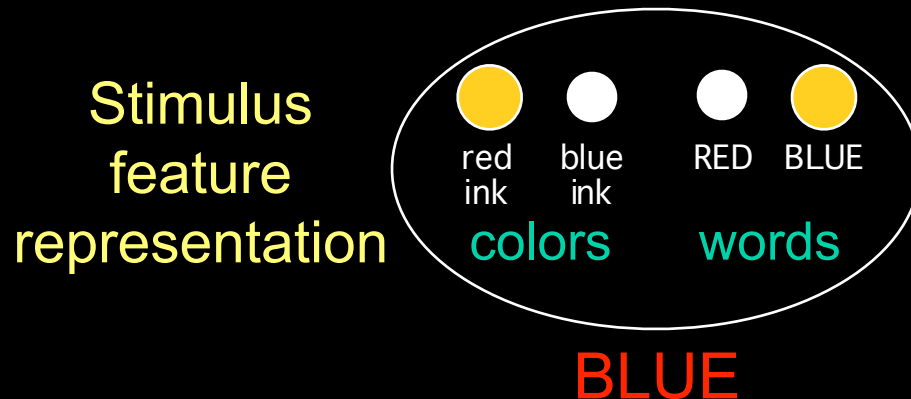
Processes that flexibly shape and constrain our thoughts, memories, and actions in view of our **goals** and the current **context**



Putative cognitive control functions include

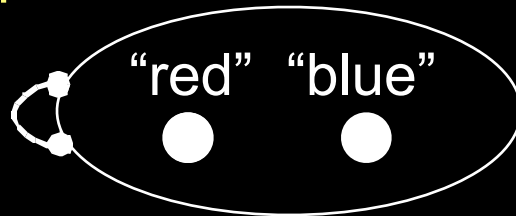
- **Inhibition** of automatic or prepotent responses
- **Selection** of relevant representations / responses
- **Shifting** of attention
- **Updating & monitoring** of working memory

Cognitive Control: Overriding Competition from Automatically Retrieved Information

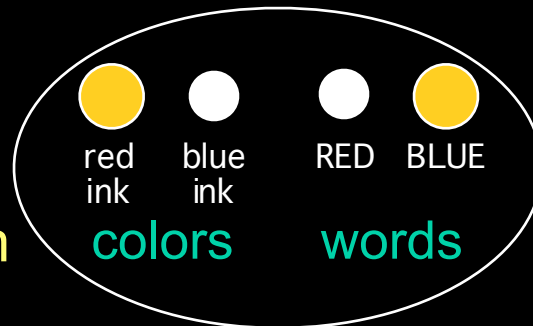


Cognitive Control: Overriding Competition from Automatically Retrieved Information

Verbal
response

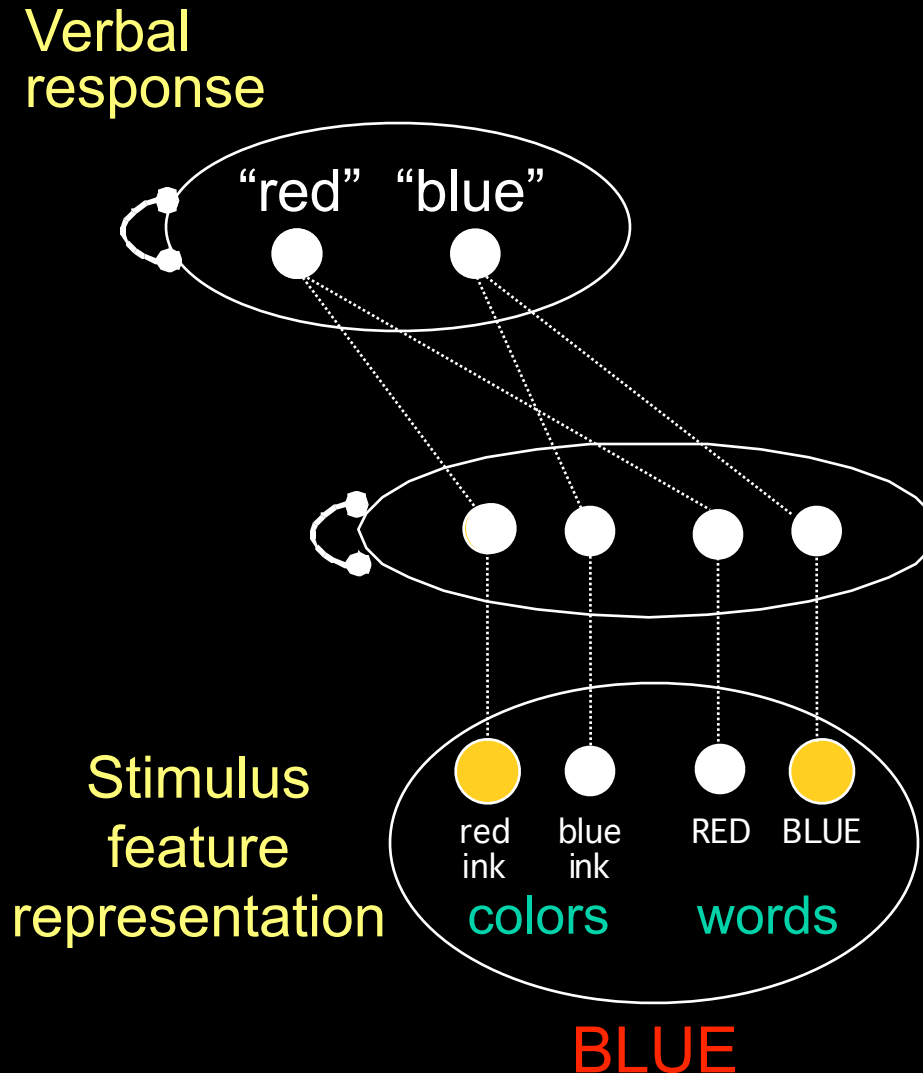


Stimulus
feature
representation

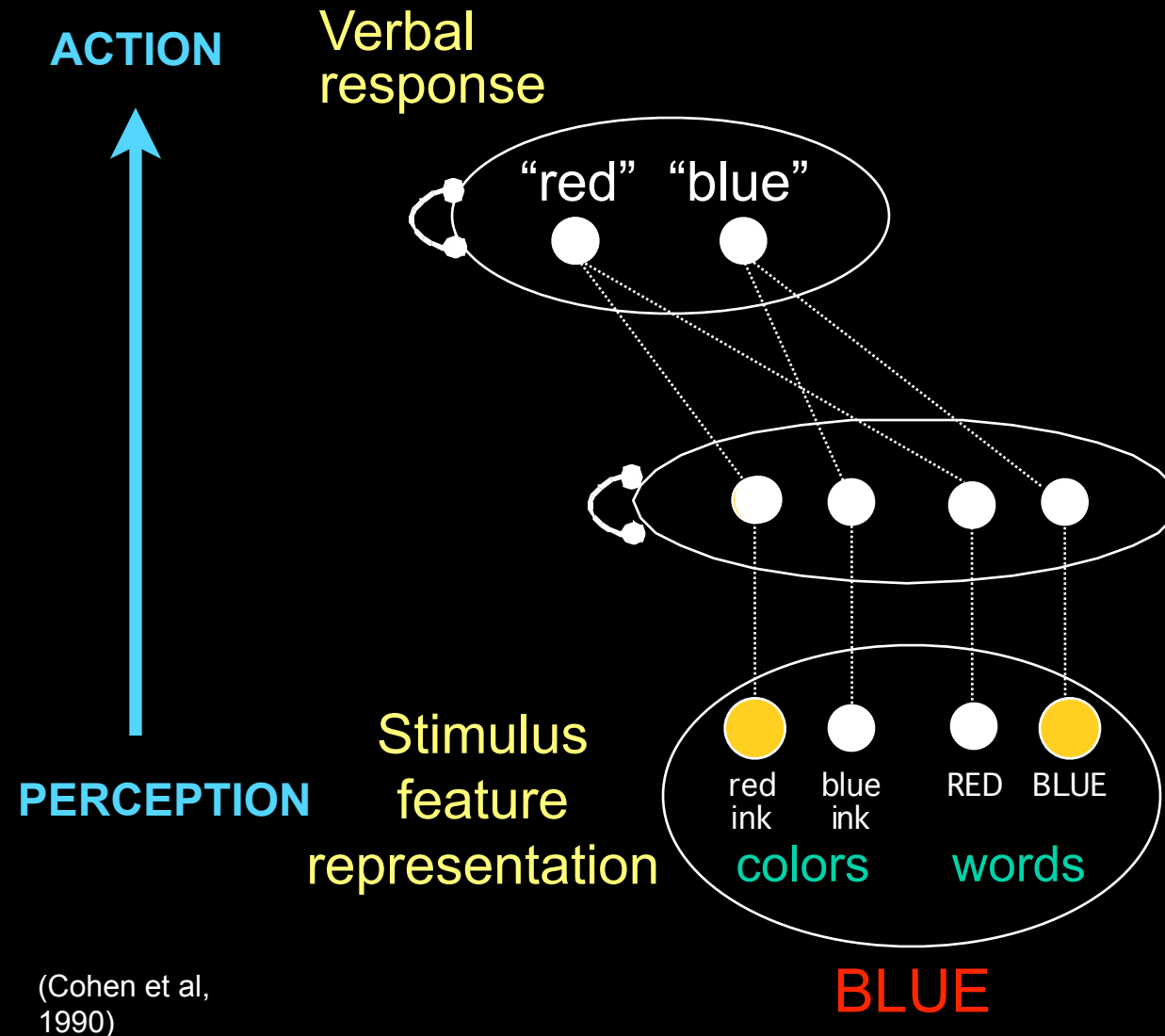


BLUE

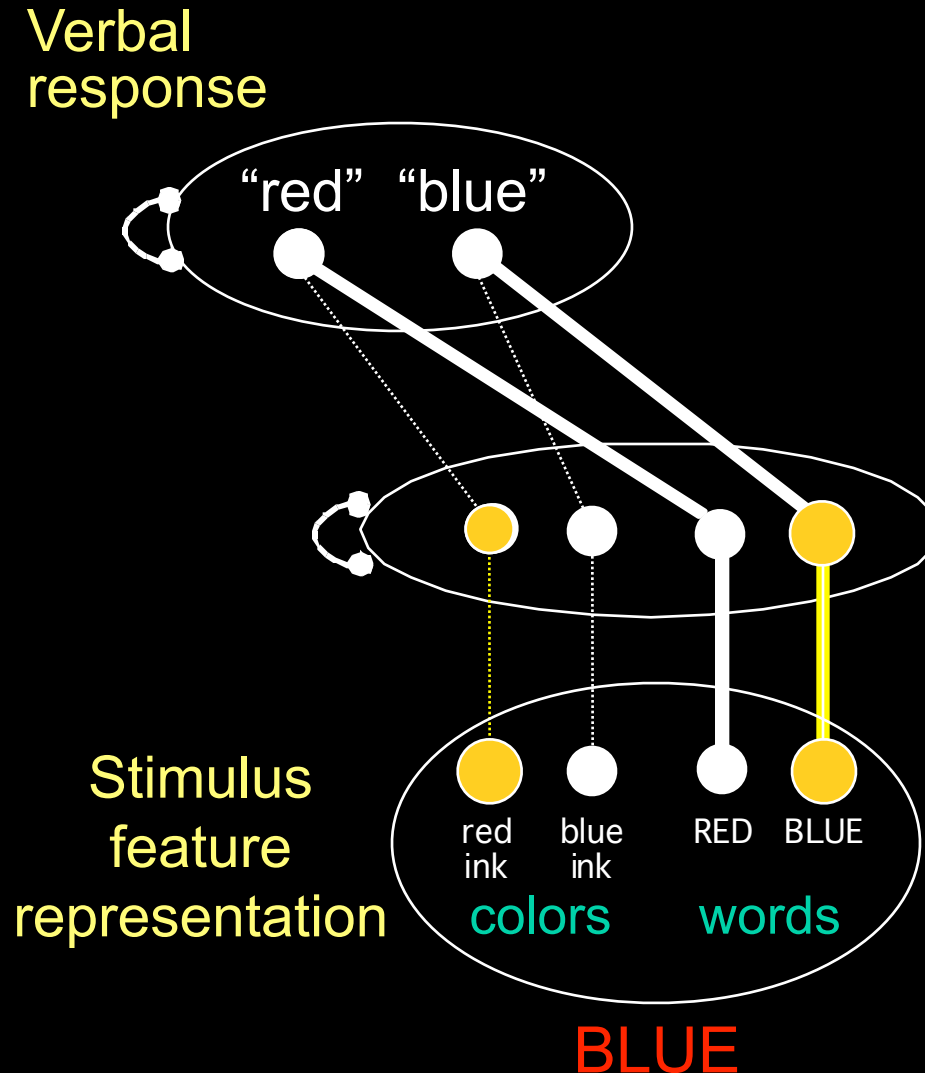
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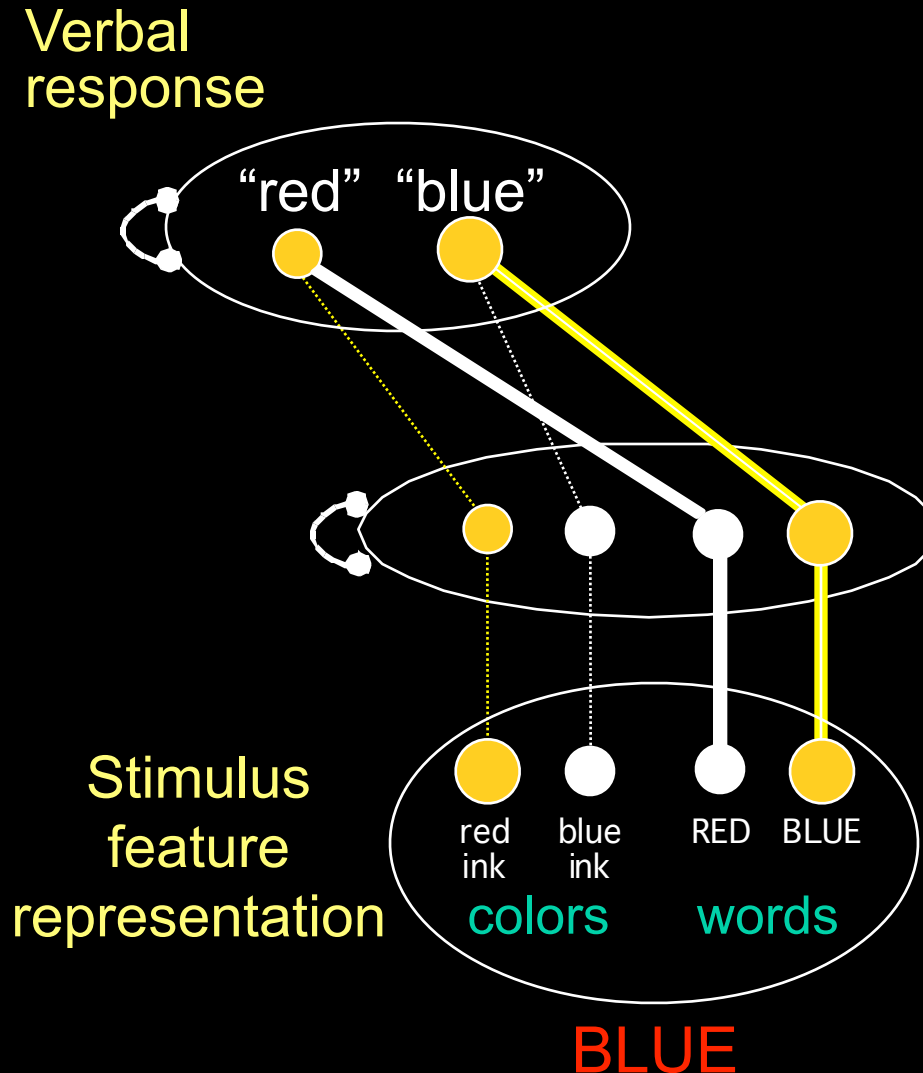


Executive Control: Overriding Competition from Automatically Retrieved Information

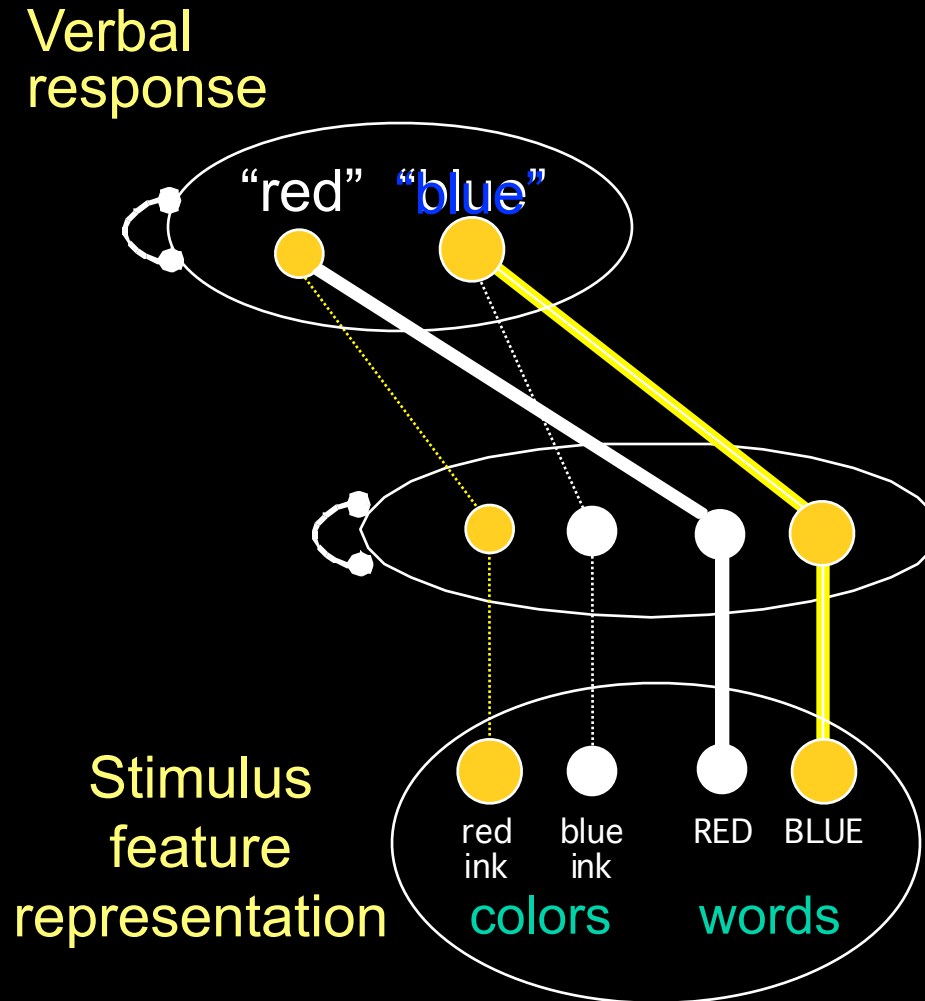


(Cohen et al, 1990)

Cognitive Control: Overriding Competition from Automatically Retrieved Information



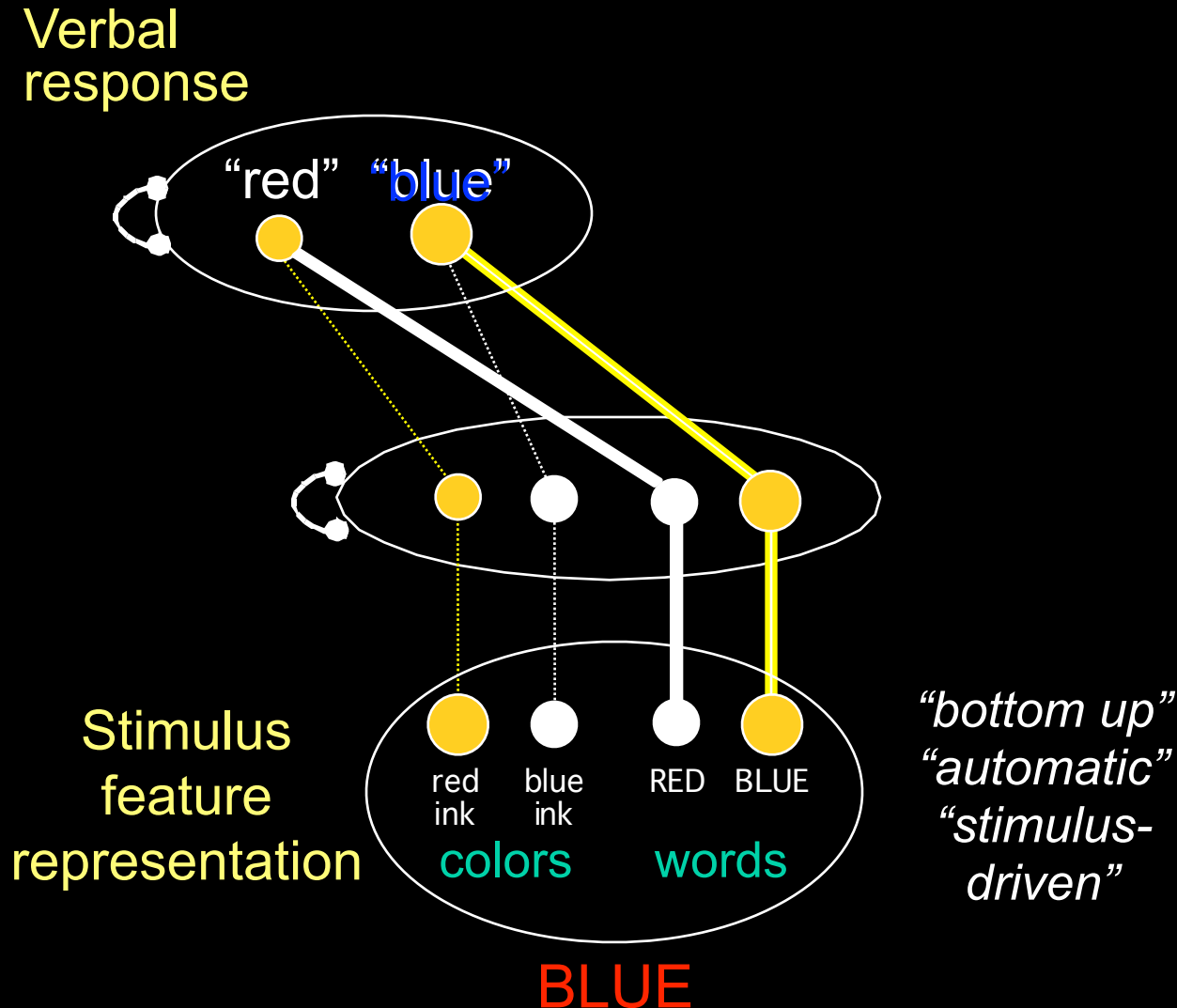
Executive Control: Overriding Competition from Automatically Retrieved Information



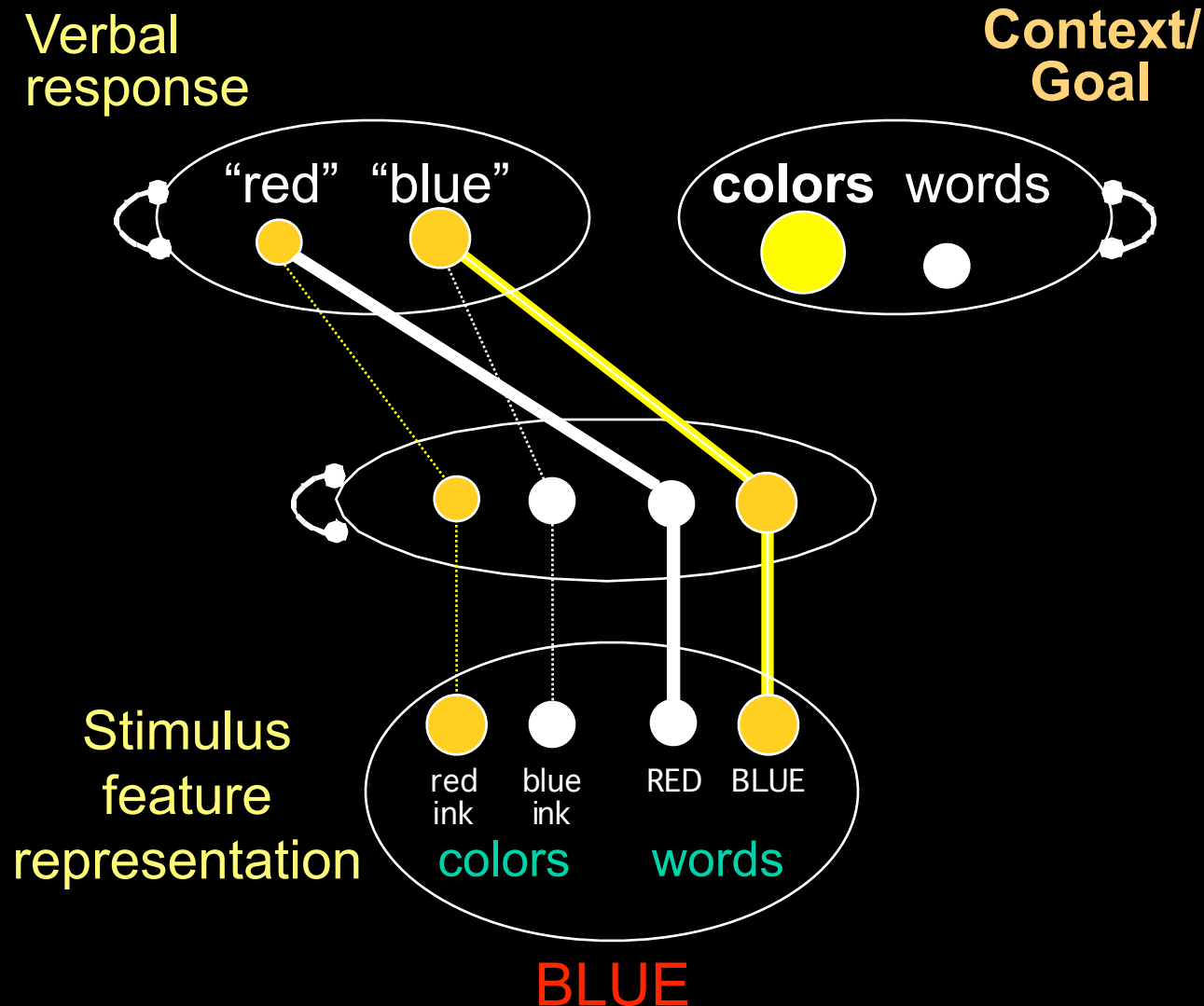
(Cohen et al, 1990)

BLUE

Cognitive Control: Overriding Competition from Automatically Retrieved Information

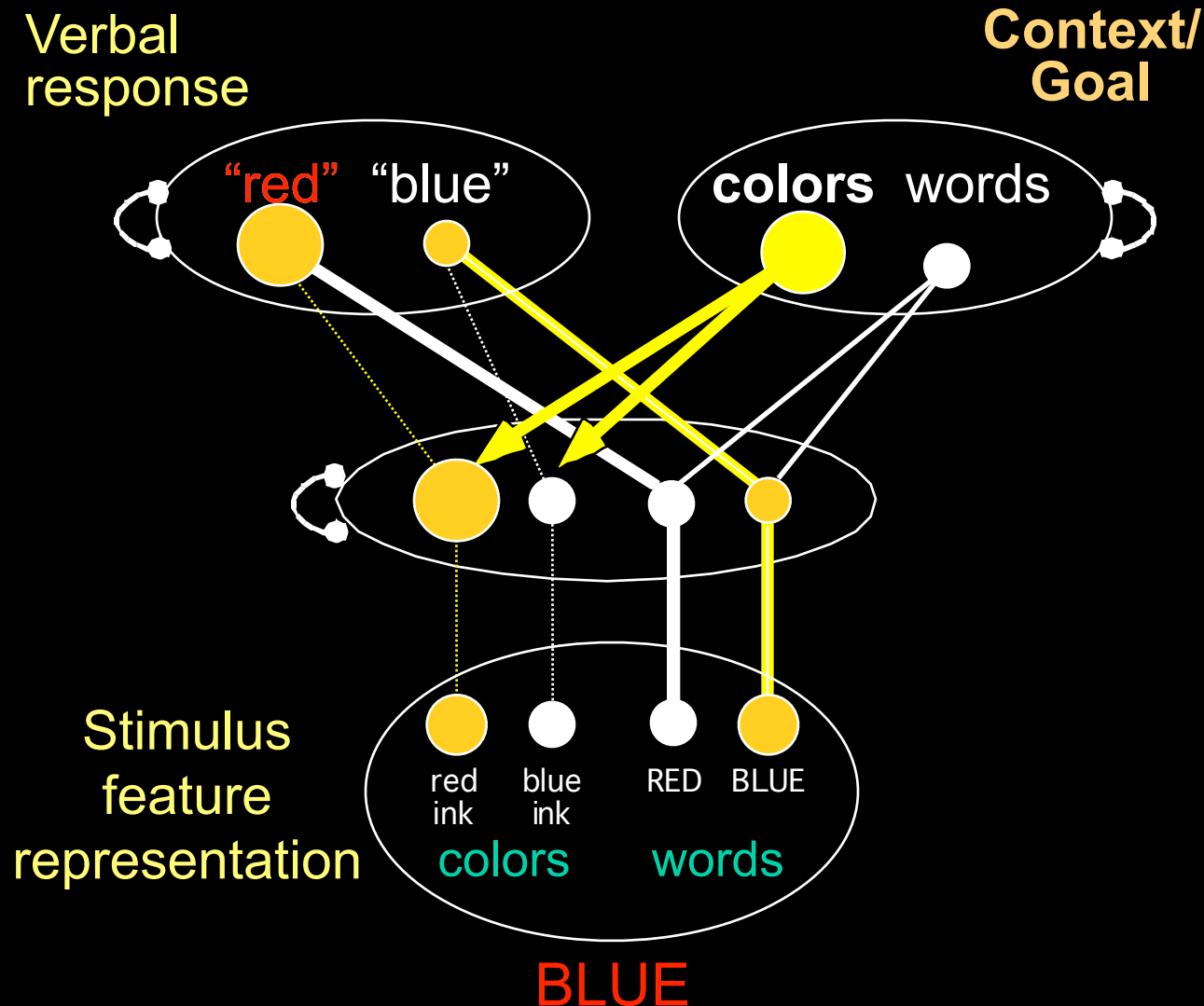


Executive Control: Overriding Competition from Automatically Retrieved Information

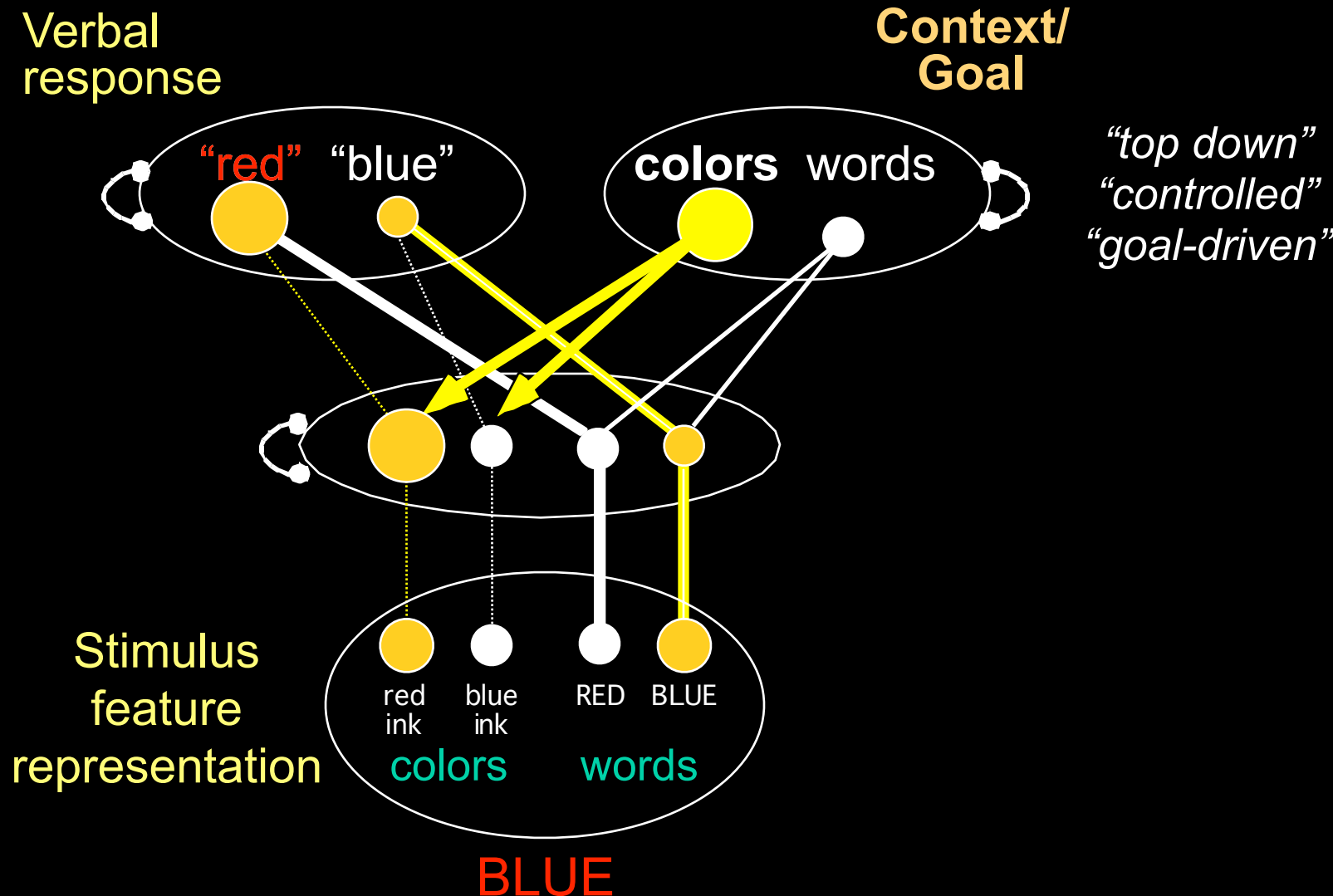


(Cohen et al, 1990)

Cognitive Control: Overriding Competition from Automatically Retrieved Information



Cognitive Control: Overriding Competition from Automatically Retrieved Information



Automatic and Controlled Processing

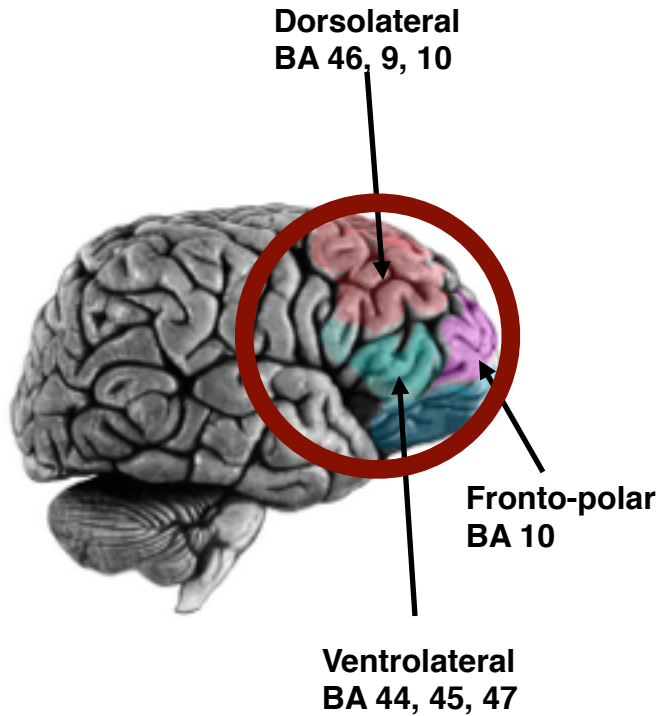
Automatic	Controlled
rapid	slower
obligatory / does not require conscious effort	effortful / not obligatory
recovers task relevant or irrelevant knowledge	recovers relevant knowledge even in the face of competition

Outline

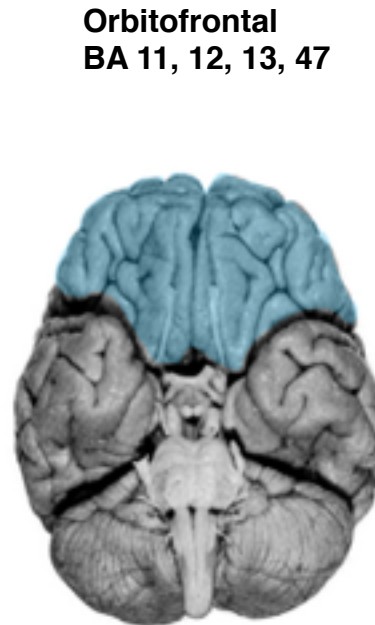
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FRONTAL SUBDIVISIONS



COGNITION

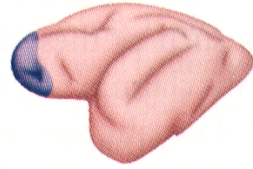


SOCIAL/EMOTIONAL

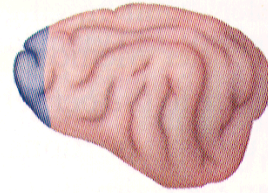


INTERPLAY

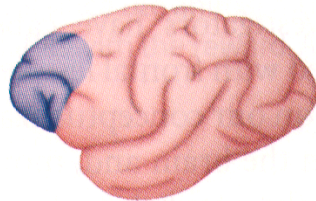
Neurobiology of Cognitive Control: PFC



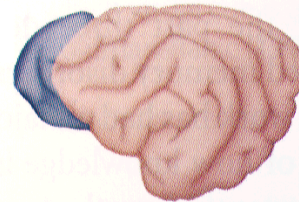
Squirrel monkey



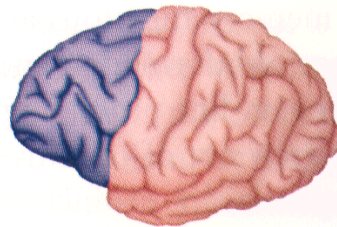
Cat



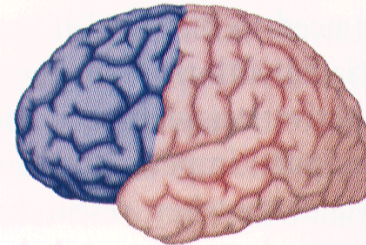
Rhesus monkey



Dog



Chimpanzee

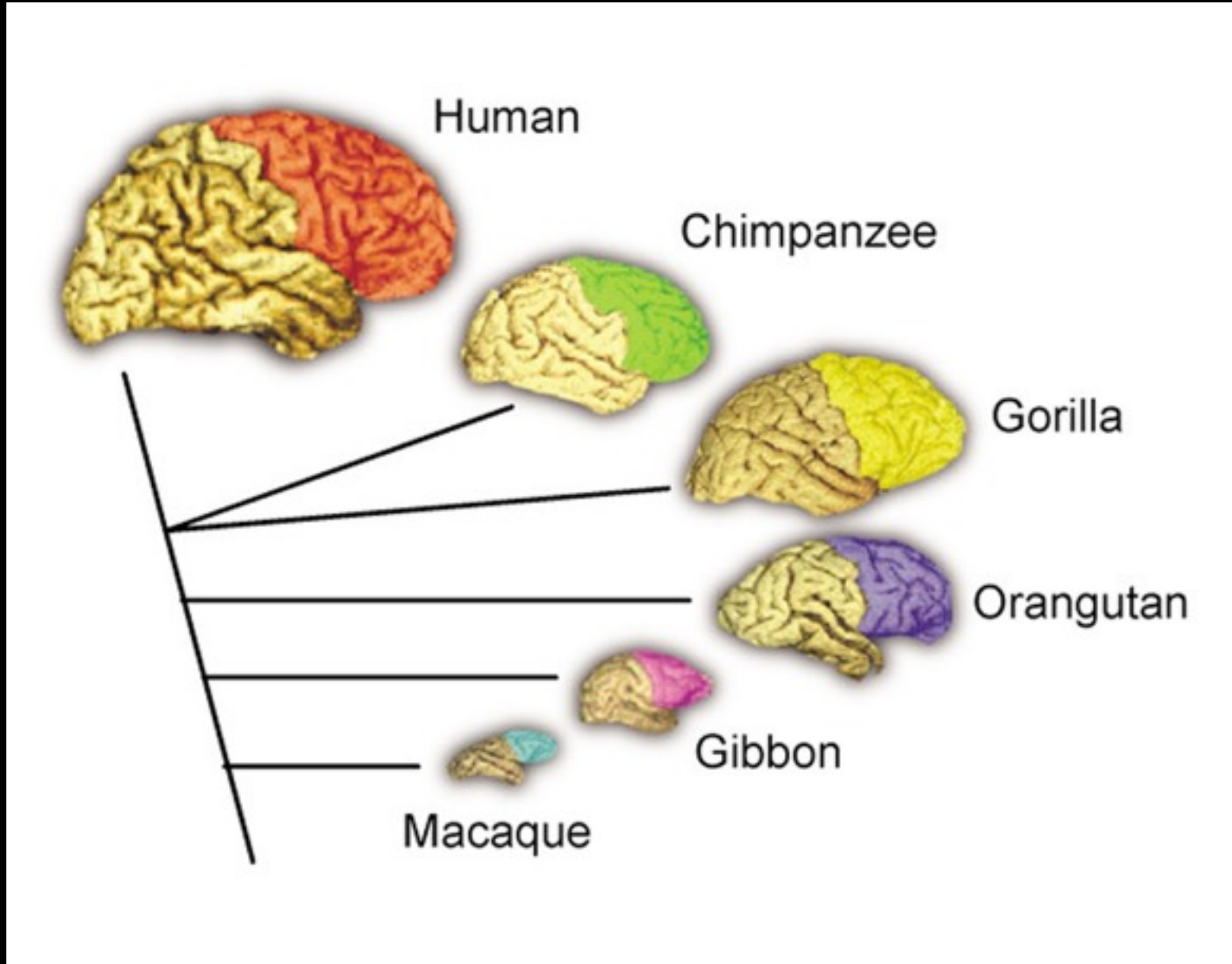


Human

*Long-held dogma:
PFC is
proportionally
larger in humans
than other primates*

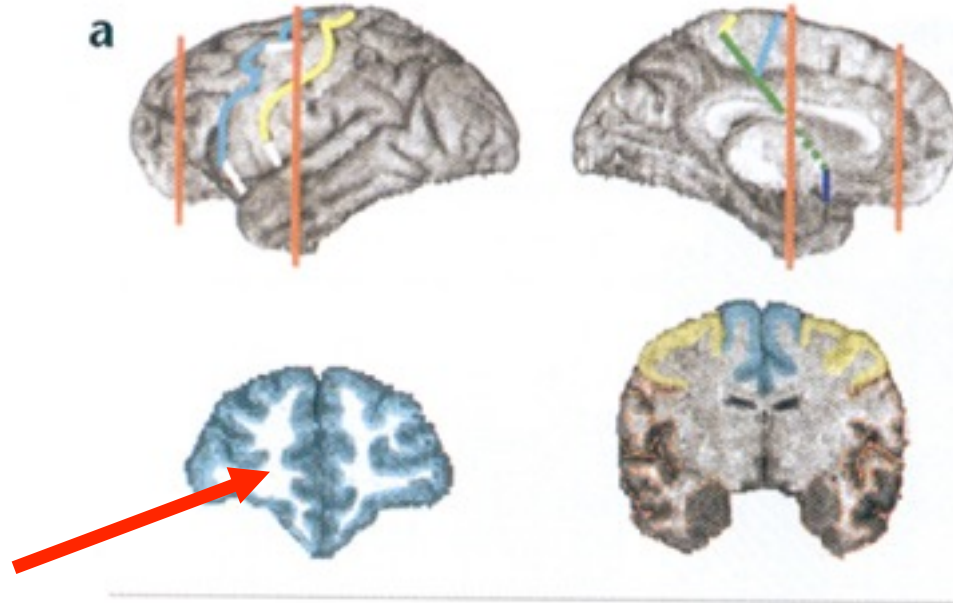
Adapted from Fuster, 1989

True Frontal Lobe Size in Humans and Apes

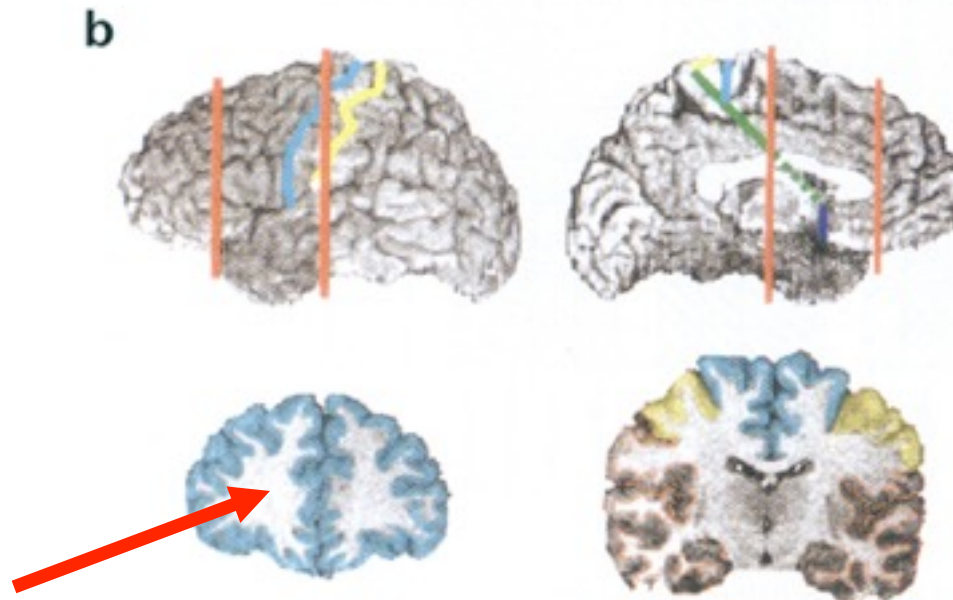


Increased PFC Connectivity in Humans

Chimpanzee

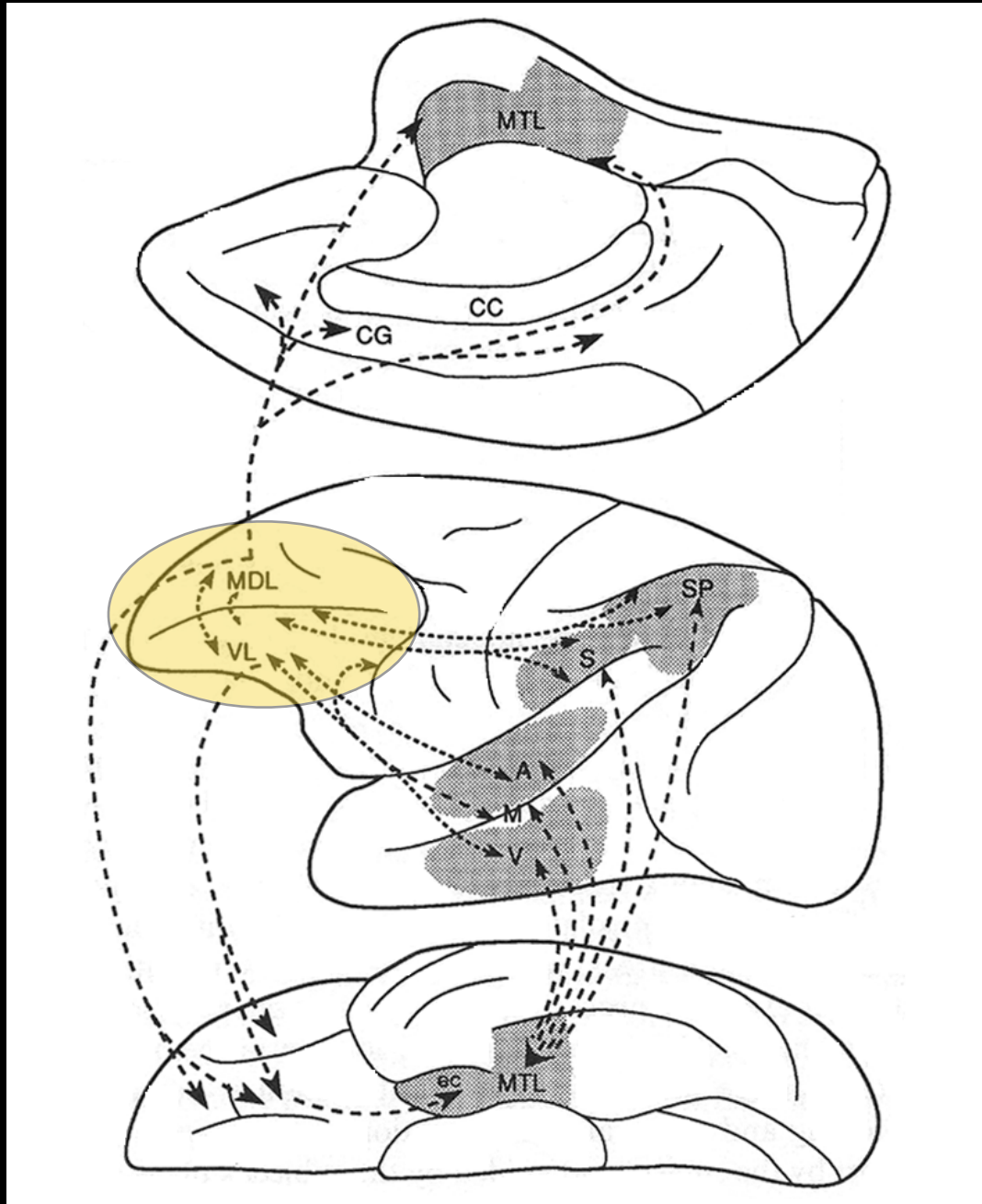


Human

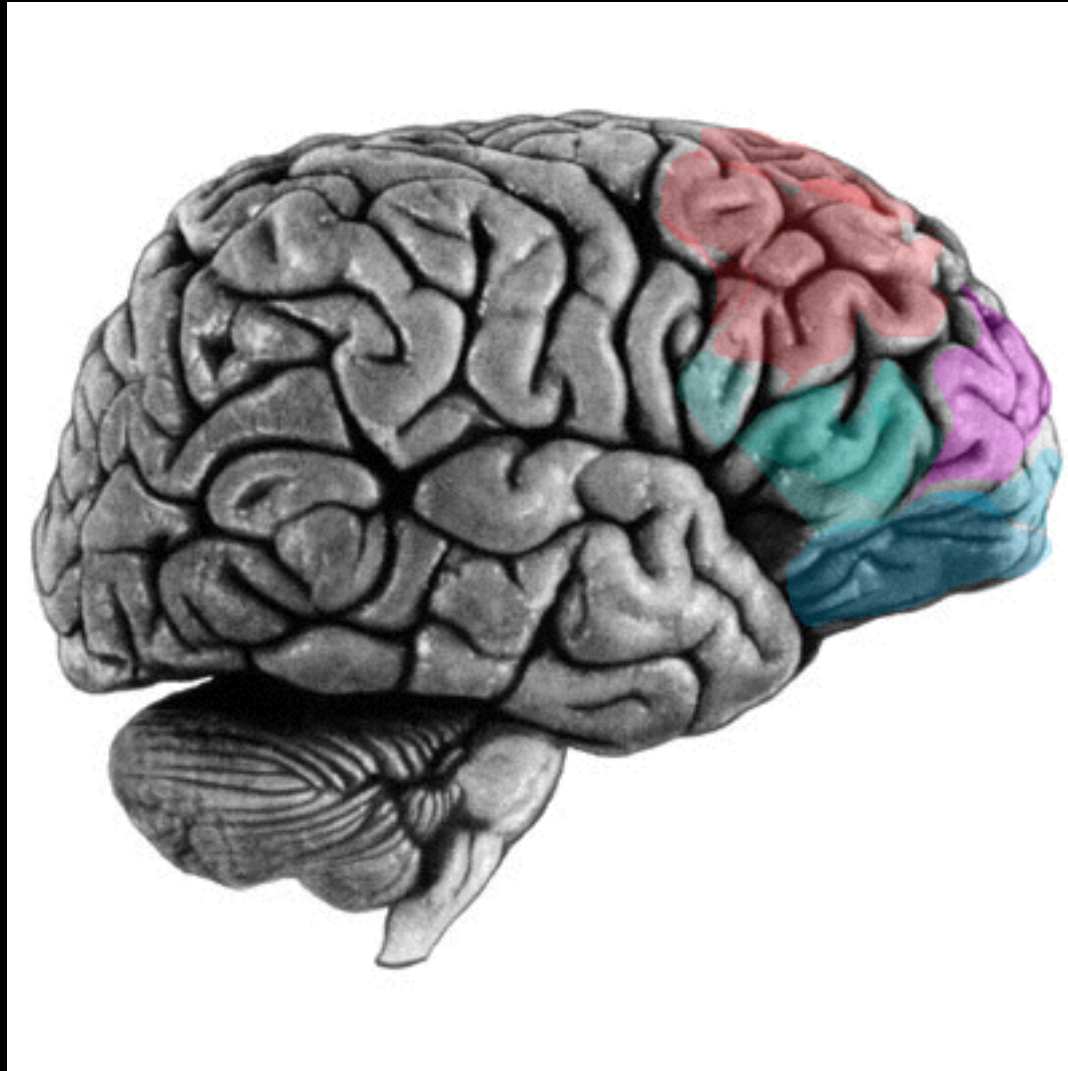


Prefrontal – Posterior Cortical Circuits

MDL = Dorsolateral PFC
VL = Ventrolateral PFC



Cognitive Control and Lateral Prefrontal Cortex

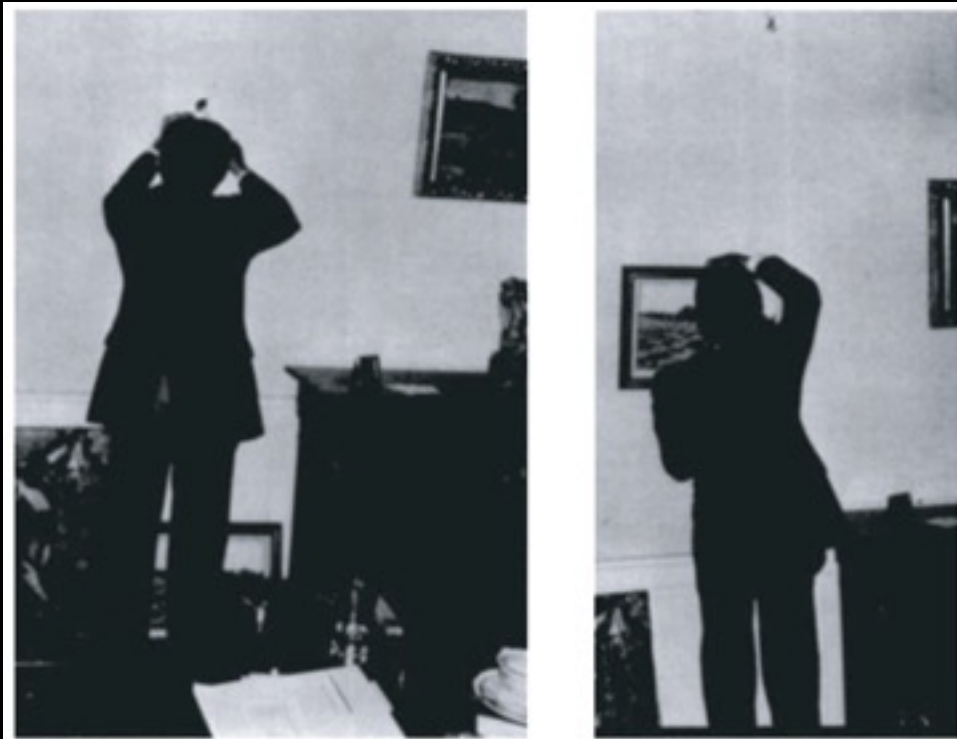


Lateral PFC Lesions: Deficits in Cognitive Control

Reactive Control

- increased distractibility (reminder: Jacobson lesion study)
- utilization / imitation behavior
- perseverative thoughts, response tendencies
- inability to inhibit inappropriate responses

Utilization Behavior



Imitation Behavior



B









D










E

(Lhermitte, 1983; 1986)








Perseveration

Cross	Circle	Cross	Circle	Cross	Circle
					







Patient Kryl. Intracerebral tumor of the left frontal lobe.

Circle	Square	Circle	Square	Circle	Circle	Circle
						

Patient Giash. Intracerebral tumor of the left frontal lobe.

Circle	Cross	Circle	Cross	Cross	Cross	Cross
						

Patient Pas. Abscess of the right frontal lobe.

Circle	One circle	Cross	Square	Triangle	Circle
					

Patient Step. Intracerebral tumor of the left frontal lobe.

Lateral PFC Lesions: Deficits in Cognitive Control

Reactive Control

- increased distractibility
- utilization / imitation behavior
- perseverative thoughts, response tendencies
- inability to inhibit inappropriate responses

Proactive Control

- inability to maintain information in the face of interference
- difficulty planning ahead, strategizing
- inactivity / initiation difficulties
- reliance on external cues to initiate behavior

Outline

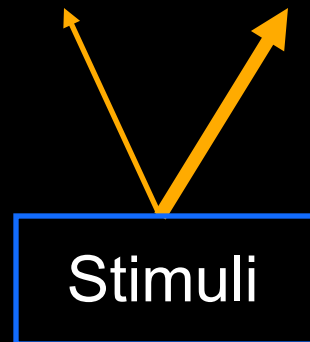
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Single or Multiple Process Theories of Cognitive Control

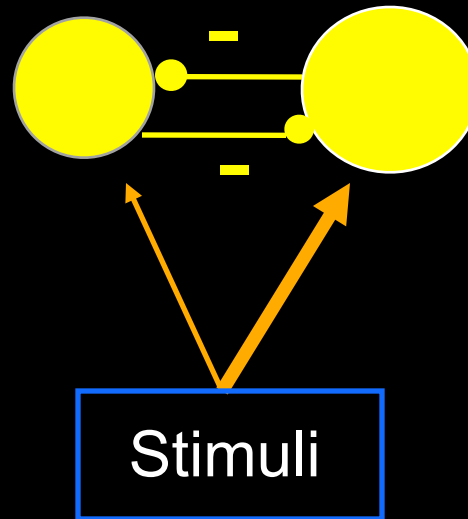
- Biased–Competition Theory (**single** form of control)
- Multi-Process Theories

PFC and Bias Competition Theory



PFC and Bias Competition Theory

Representations

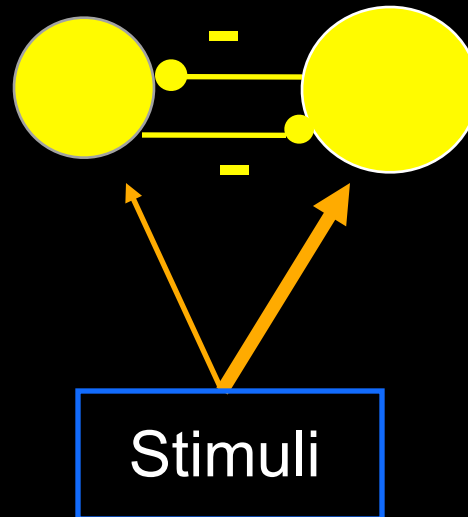


PFC and Bias Competition Theory

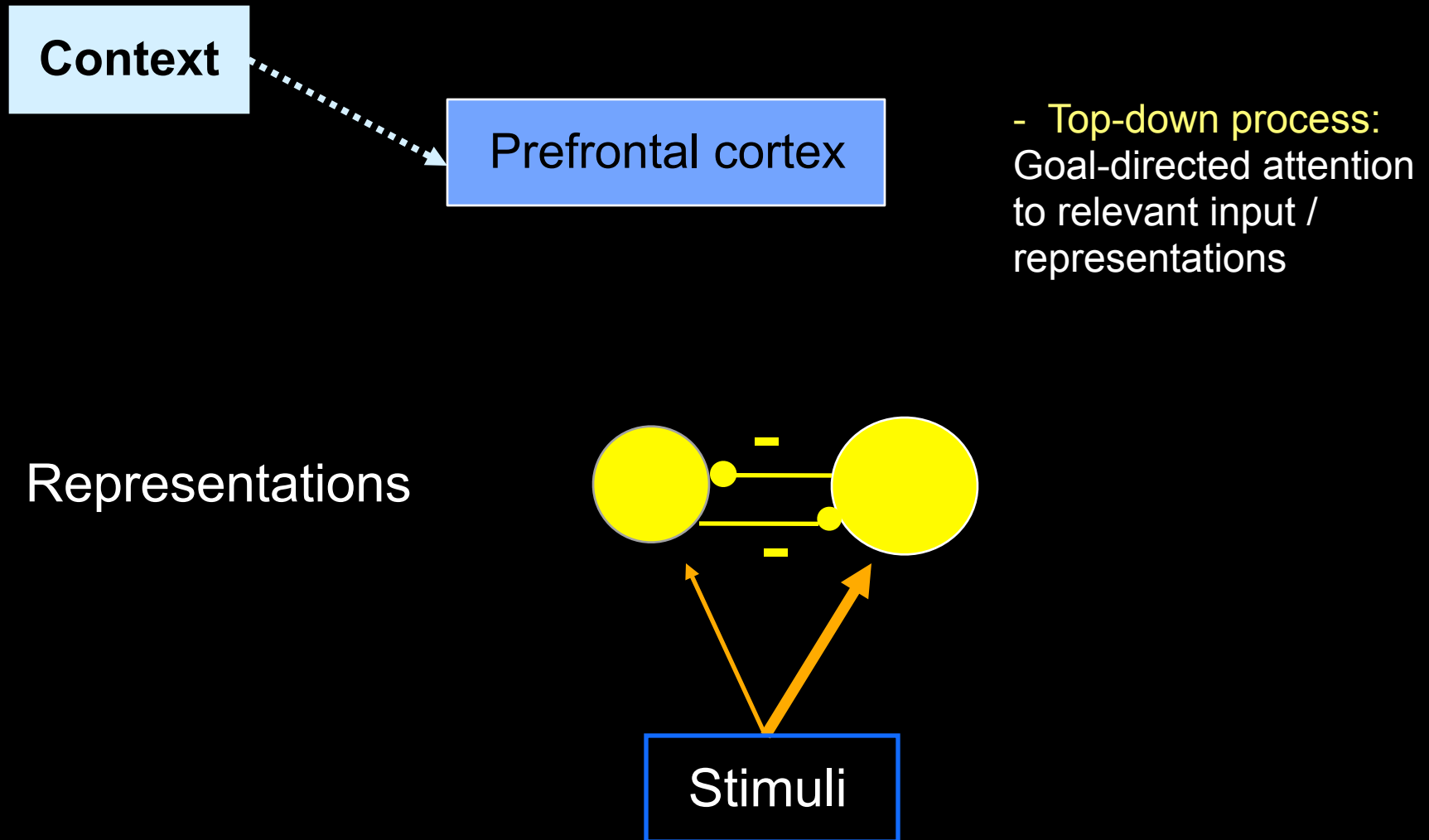
Prefrontal cortex

- Top-down process:
Goal-directed attention
to relevant input /
representations

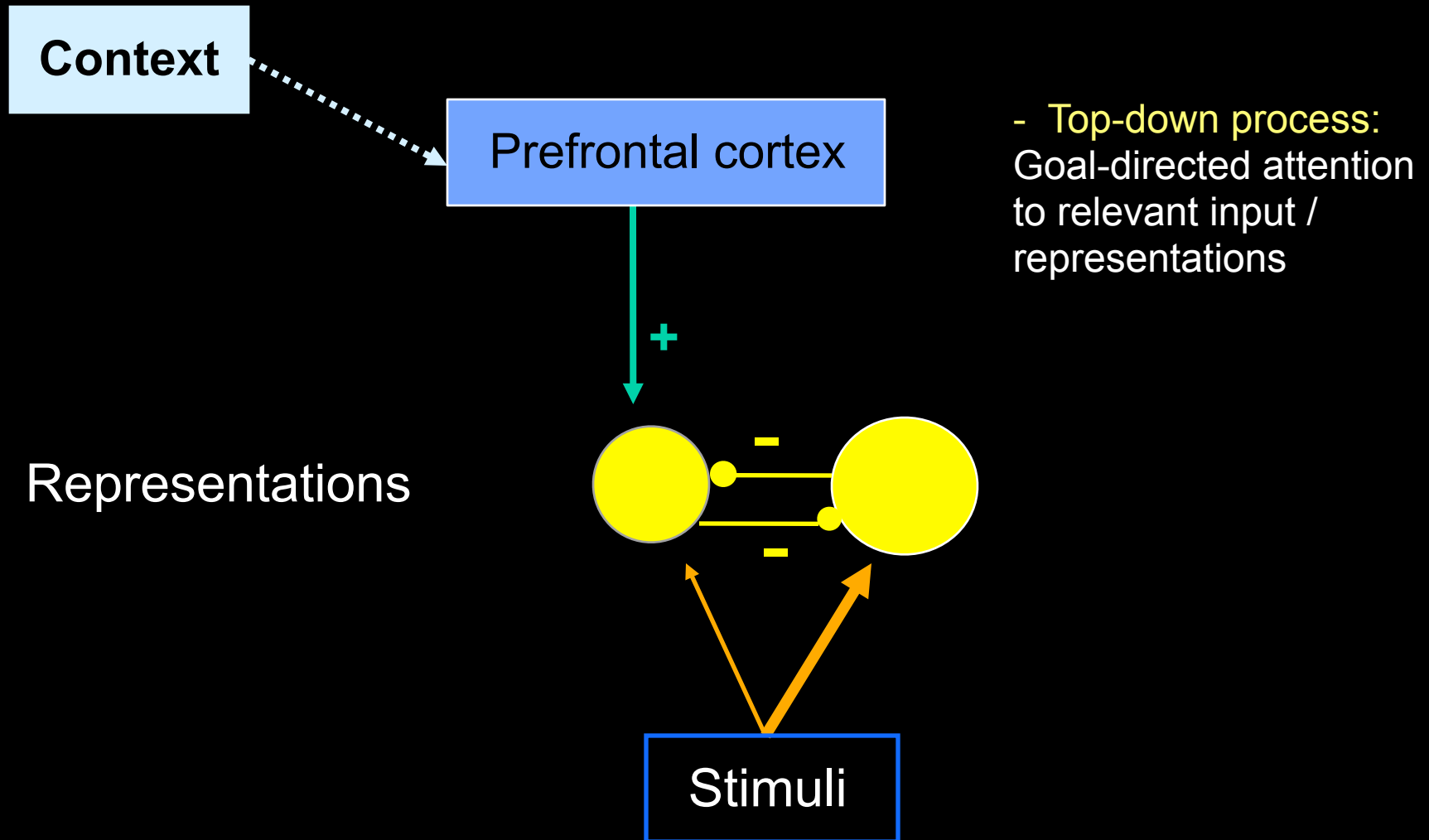
Representations



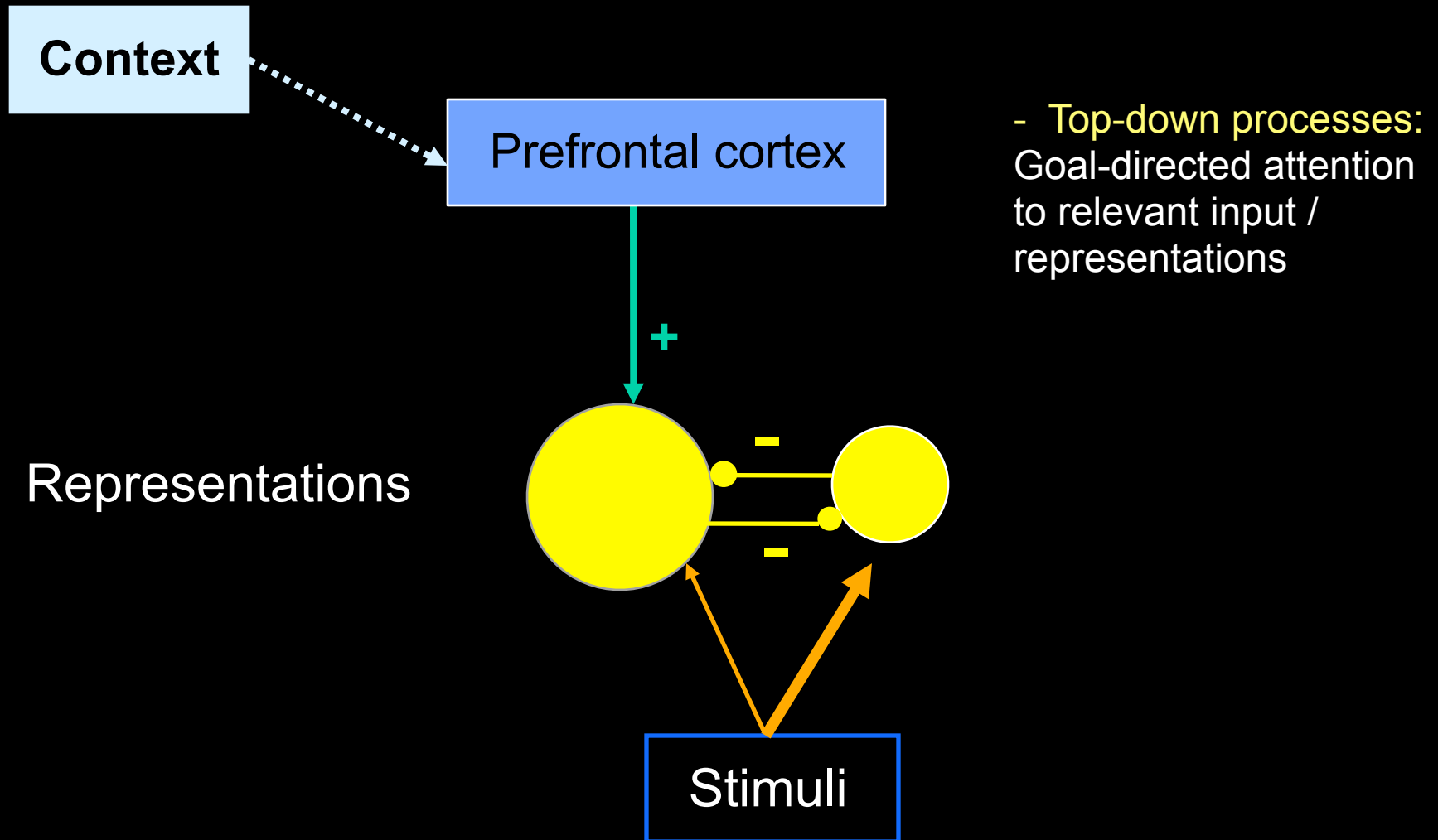
PFC and Bias Competition Theory



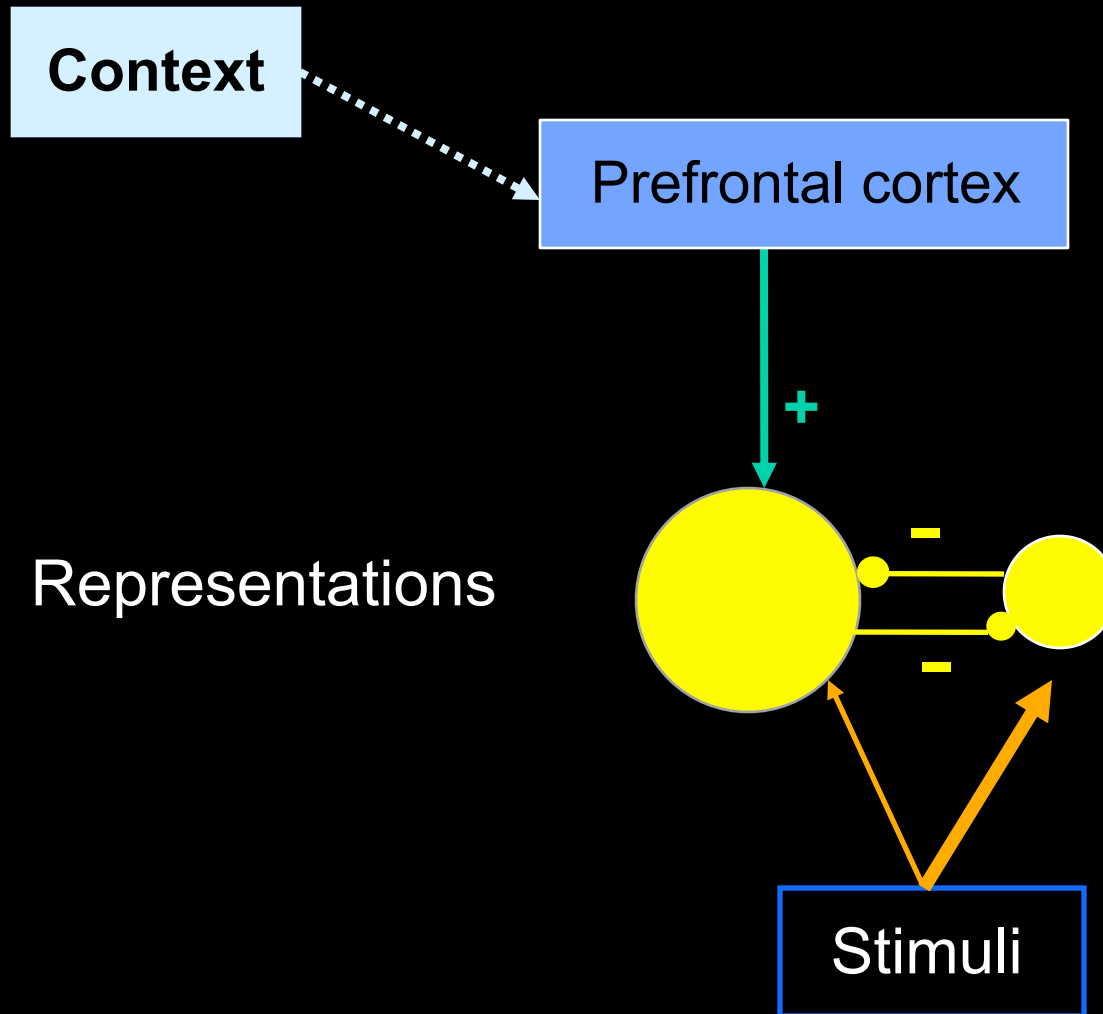
PFC and Bias Competition Theory



PFC and Bias Competition Theory



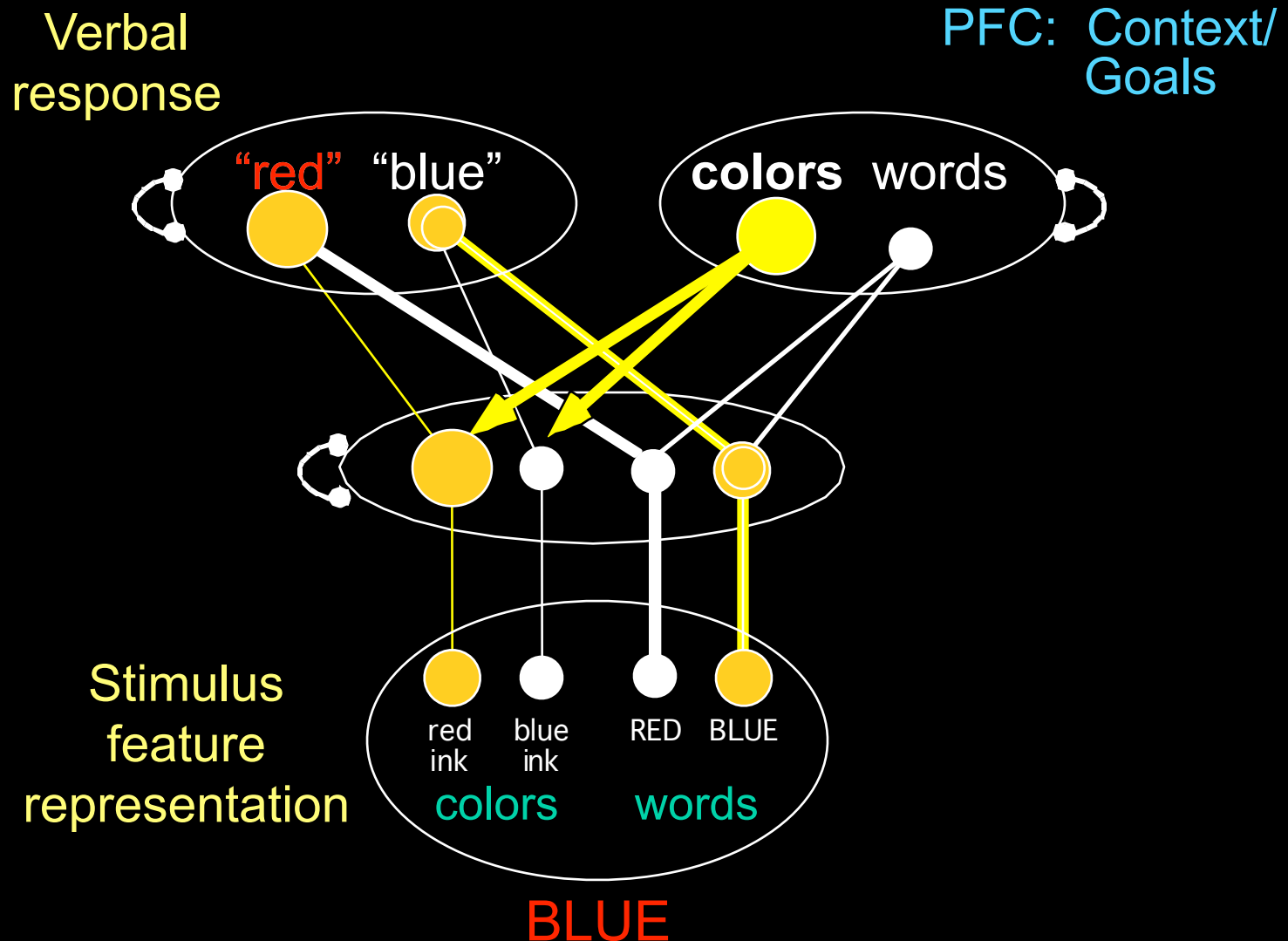
PFC and Bias Competition Theory



- **Top-down processes:**
Goal-directed attention
to relevant input /
representations

- **Indirect Inhibition:**
Competition in
representational cortex
results in inhibition of
irrelevant
representations with
relevant representations
are attended / selected

Cognitive Control: Selection (& Indirect Inhibition) in the Face of Competition



Single or Multiple Process Theories of Cognitive Control

- Biased–Competition Theory (**single** form of control)
- Multi-Process Theories

CEO or Executive Committee?

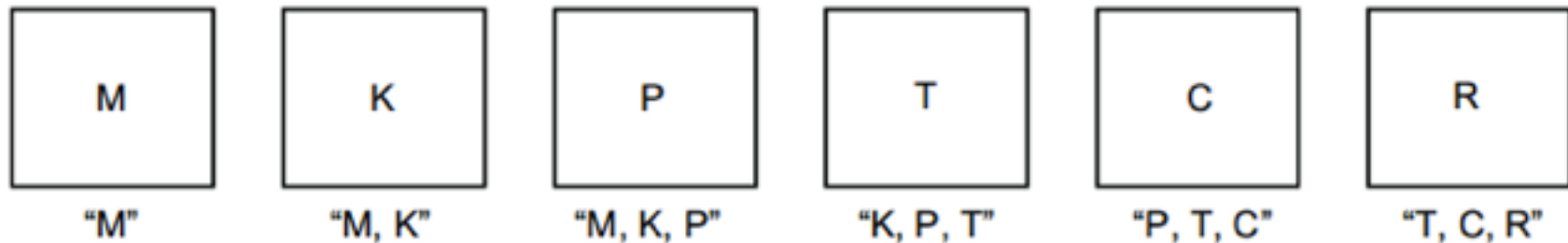
“Whether we will . . . be left with a single coordinated system that serves multiple functions, a true executive, or a cluster of largely autonomous control processes — an executive committee — remains to be seen.”

Baddeley (1996) Exploring the central executive. *The Quarterly Journal of Experimental Psychology*, 49A, 5-28.

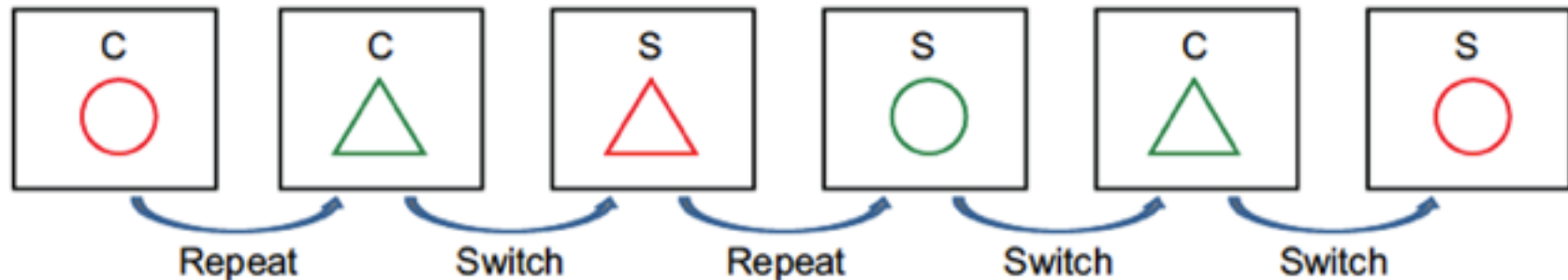
Multiple Cognitive Control Tasks

(Miyake & Friedman, 2012)

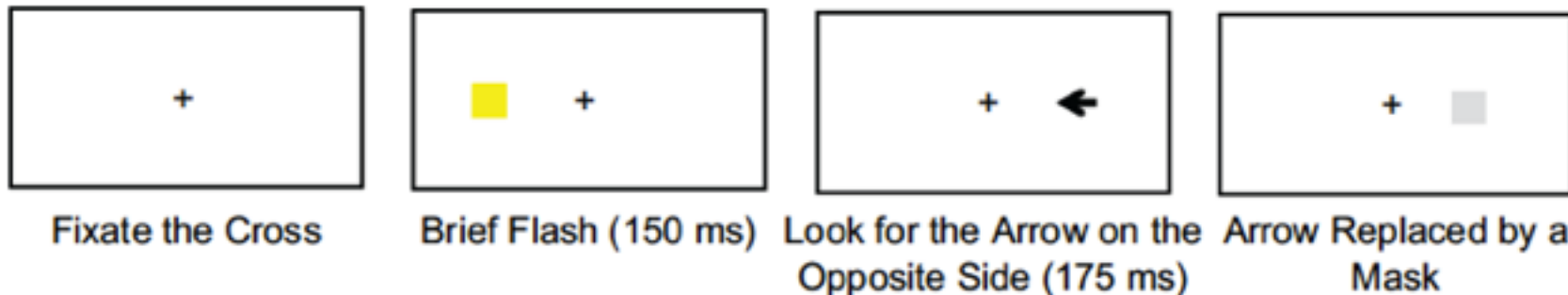
Updating: Letter Memory Task (Always Remember the Last 3 Letters)



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)



Architecture of Cognitive Control: Unity and Diversity

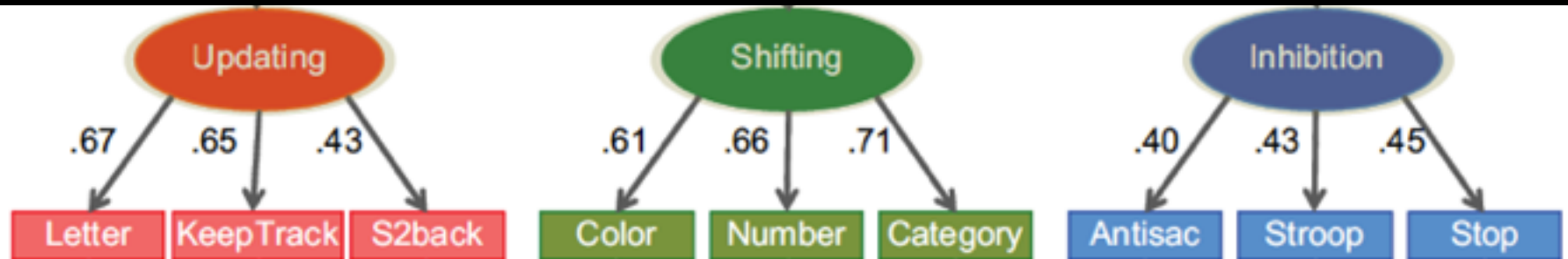
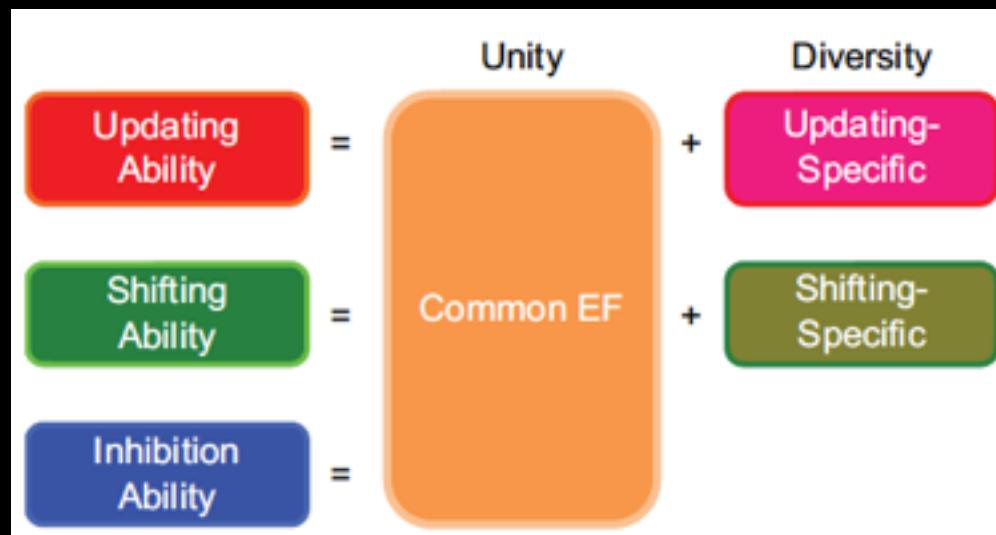
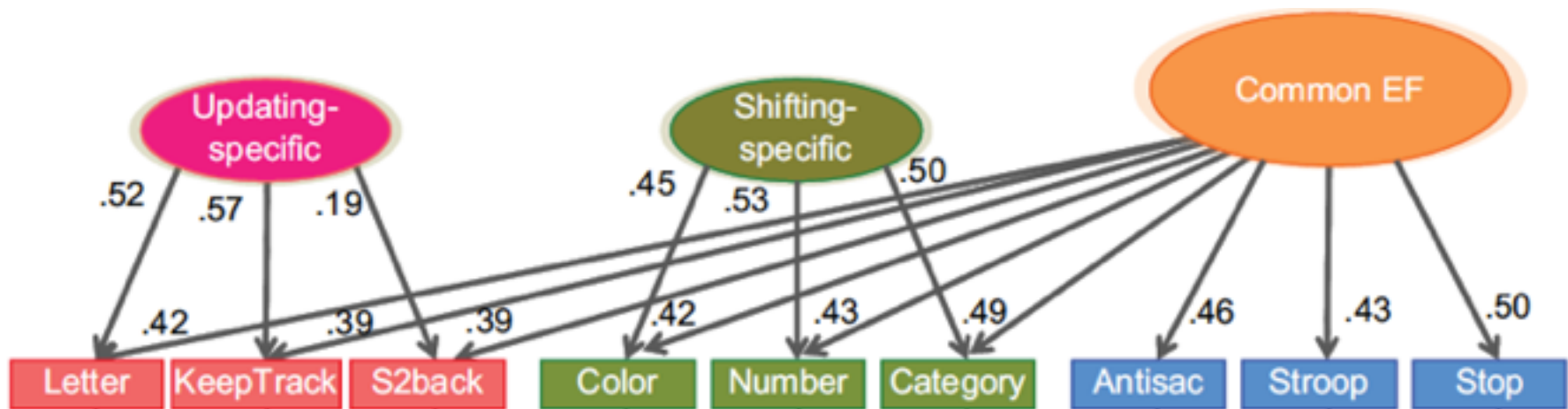


Fig. 2. Two complementary ways of representing the unity and diversity of executive functions (EFs), adapted from the confirmatory factor analysis results reported in Friedman et al. (2011; task names are abbreviated). Numbers on arrows are standardized factor loadings (values from -1 to 1 that indicate the extent to which the individual tasks are predicted by the latent variable), and those under

Architecture of Cognitive Control: Unity and Diversity



Two-Stage Model of PFC

(Petrides; Smith and Jonides)

Dorsolateral PFC



Ventrolateral PFC

- **Ventrolateral PFC (VLPFC)**
 - First level of control
 - Interacts with posterior cortical regions to select & maintain information in WM and to inhibit irrelevant information
- **Dorsolateral PFC (DLPFC)**
 - Second level of control
 - Monitors, updates, and manipulates information in WM

Two-Stage Model of PFC

(Petrides; Smith and Jonides)

Primates with lesions to DLPFC

- Perform normally on tasks requiring simple maintenance
- Are impaired on tasks requiring monitoring/updating/manipulation

Delayed non-match to sample (simple maintenance)



Monkey moves sample object for reward.

(a)



Screen obscures monkey's view during delay.

(b)

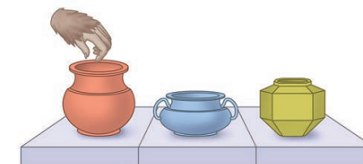


Monkey chooses novel nonmatch object.

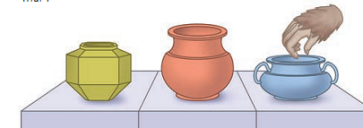
(c)

Courtesy of Daniel Vu, Marlene Machin, and Janka Terék, Laboratory of Neuroimaging, INSERM/CEM/CEM

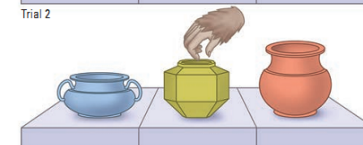
Self-ordered memory task (updating, planning)



Trial 1



Trial 2



Trial 3

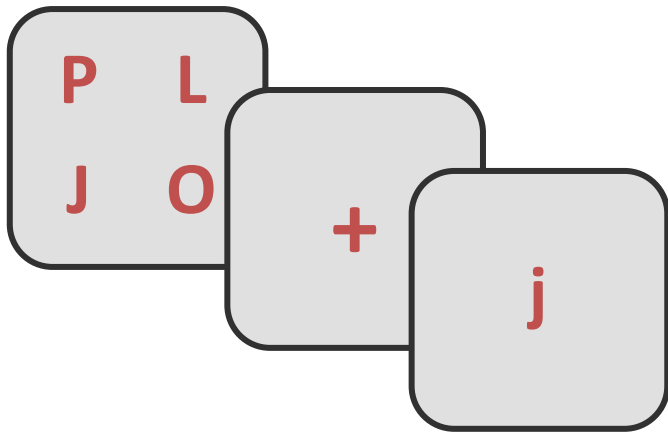
Two-Stage Model of PFC

(Petrides; Smith and Jonides)

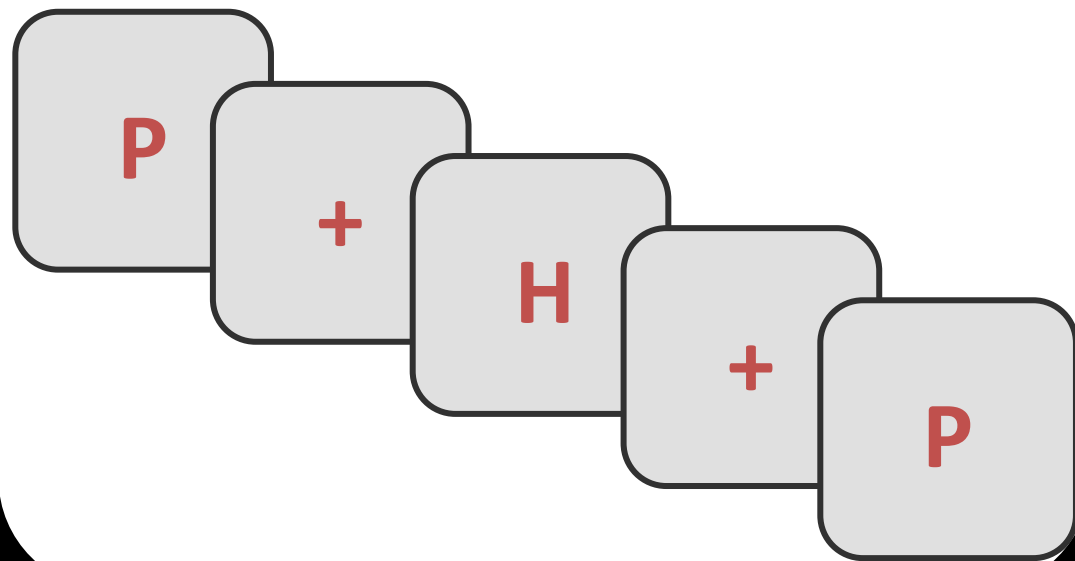
Human neuroimaging data comparing PFC activity for two tasks

- Maintenance only
- Maintenance, monitoring, and updating

Verbal item recognition (maintenance)



Verbal n-back (maintenance +)

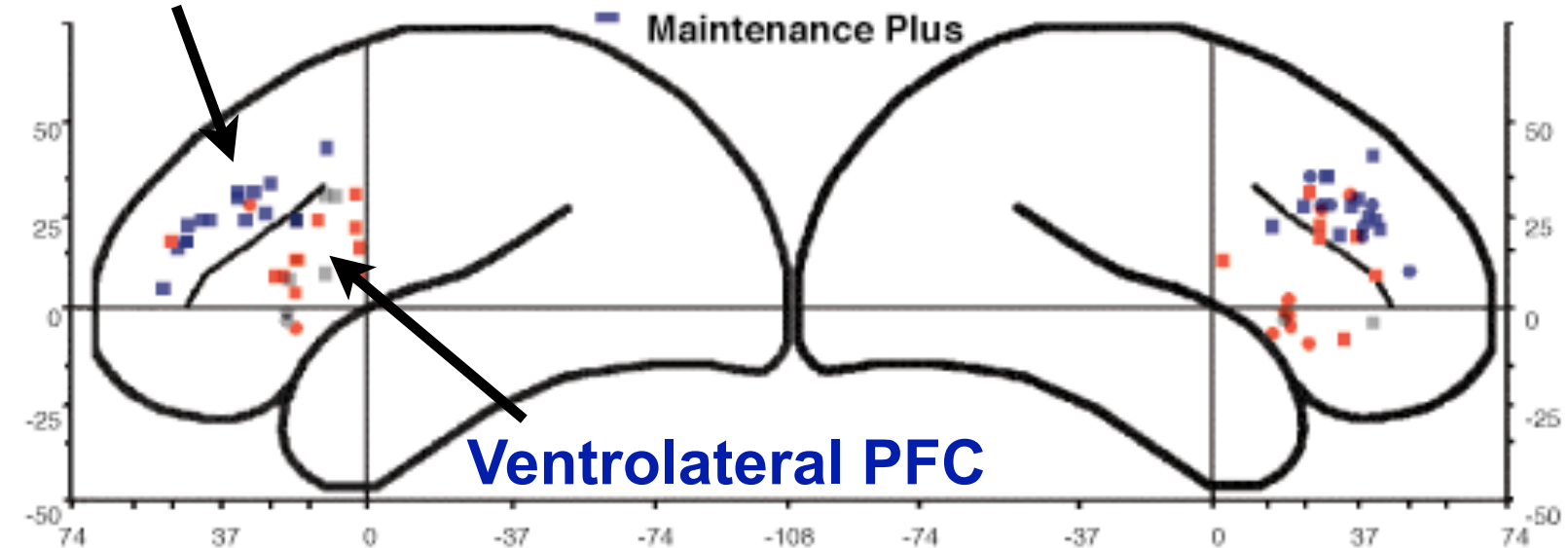


Functional Neuroimaging Evidence

(D'Esposito et al., 1998)

Dorsolateral PFC

— Maintenance Only
— Maintenance Plus



Outline

- Goal-directed (controlled) vs. Automatic Action
- What is Cognitive Control?
- Prefrontal Cortex and Cognitive Control
- Single vs. Multi-Process Theories of Control
- **What Regulates Cognitive Control?**



Regulating Cognitive Control

- How do you alter the *degree* of control?
 - You pay closer attention to the road if you're driving while it's raining as compared to while it's sunny.
 - You pay even closer attention if it's raining and dark out, than if it's raining but light out.



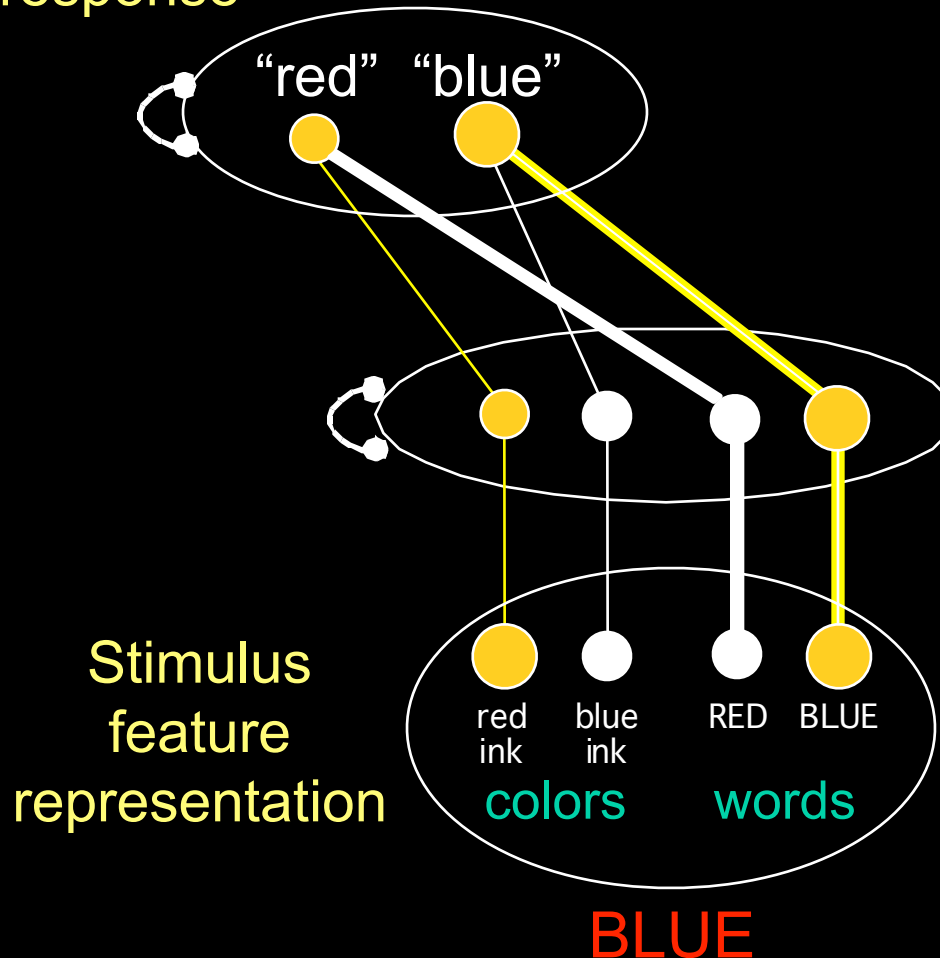
Regulating Cognitive Control

- How do you alter the *degree* of control?
 - You pay closer attention to the road if you're driving while it's raining as compared to while it's sunny.
 - You pay even closer attention if it's raining and dark out, than if it's raining but light out.
- Need a mechanism that detects the need for control

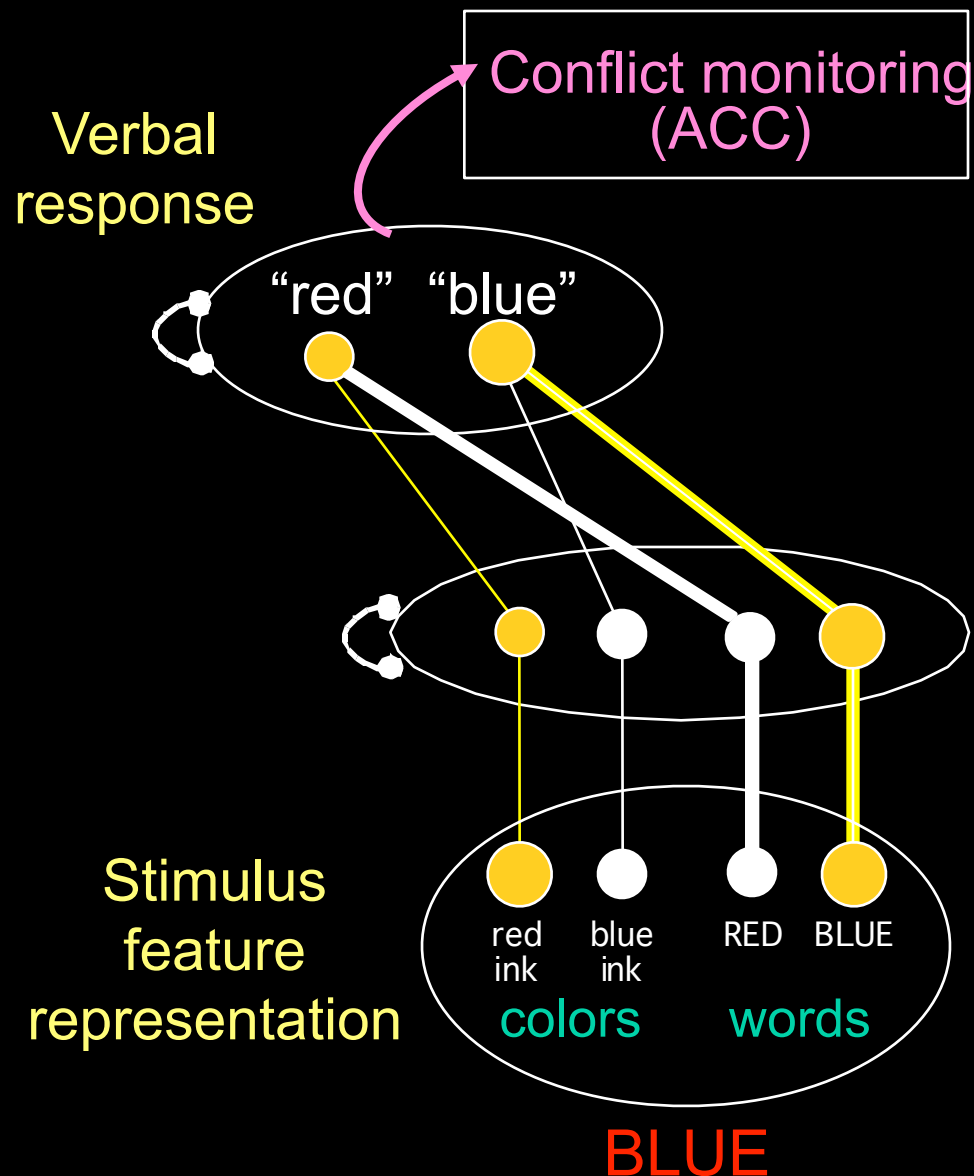


Conflict Monitoring / Error Likelihood & the Anterior Cingulate Cortex (ACC)

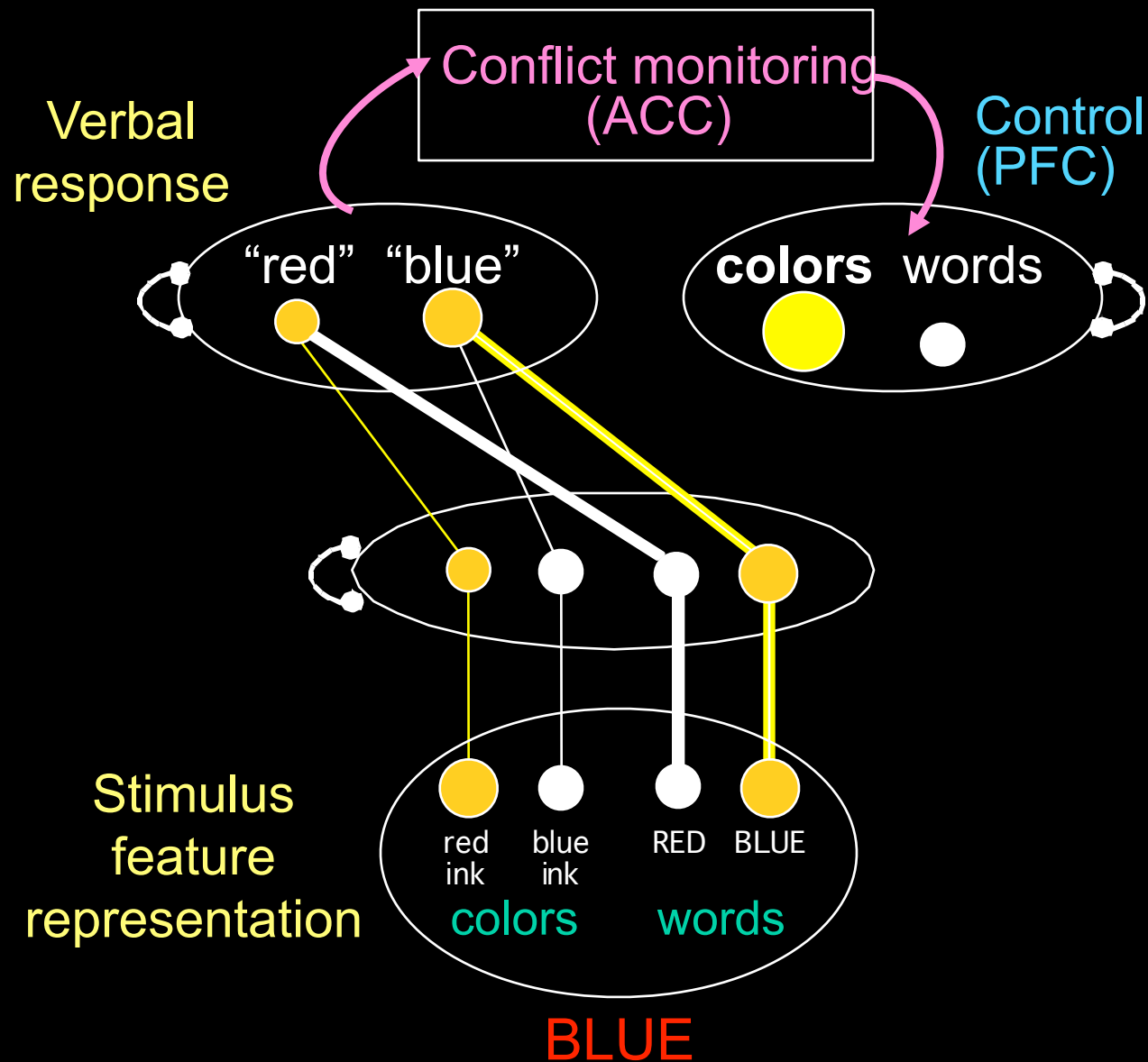
Verbal
response



Conflict Monitoring / Error Likelihood & the Anterior Cingulate Cortex (ACC)



Conflict Monitoring / Error Likelihood & the Anterior Cingulate Cortex (ACC)



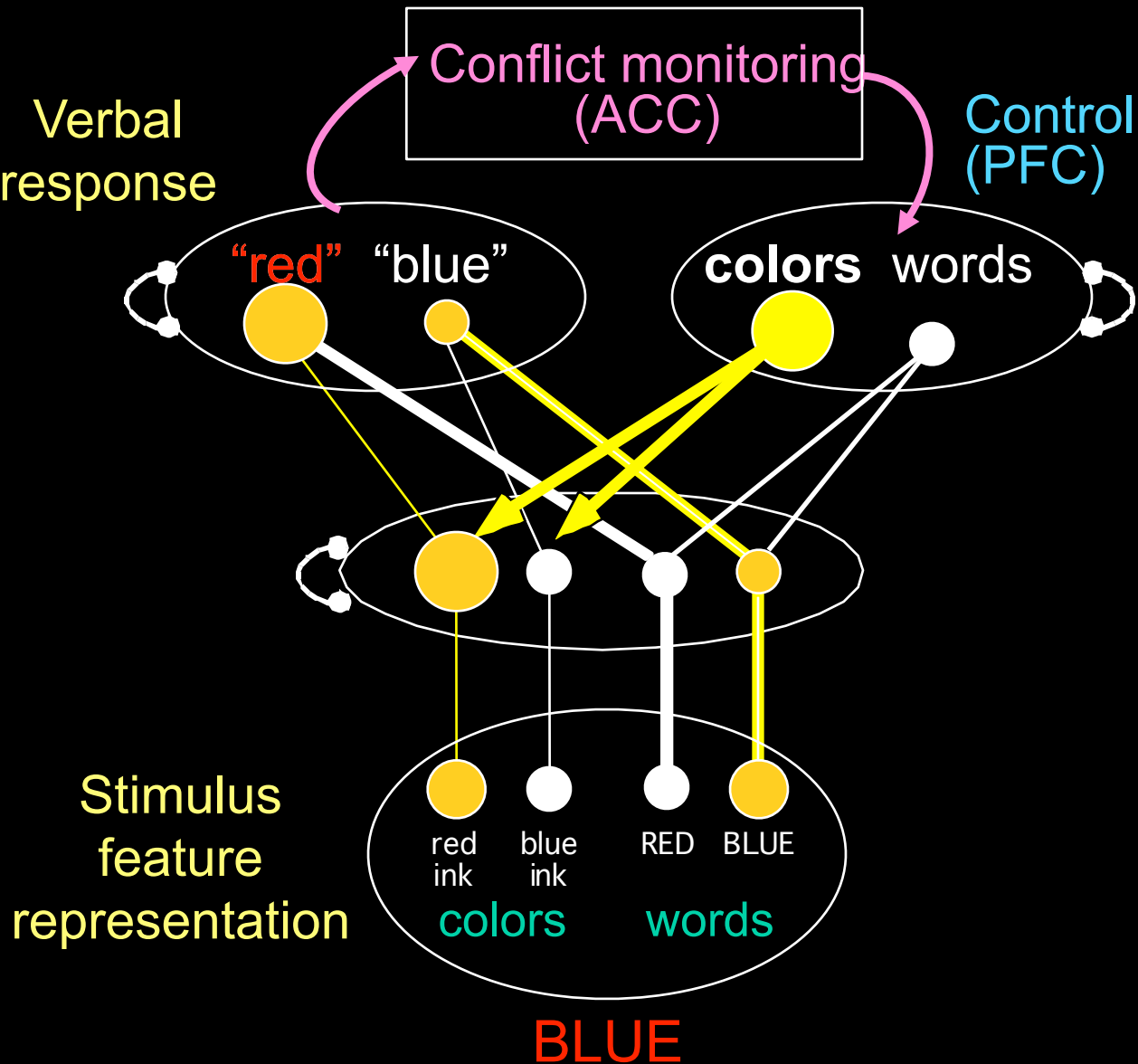
The diagram illustrates the conflict monitoring model for the Stroop task, showing the flow of information from stimulus features to verbal responses and the role of the ACC in monitoring conflict.

Stimulus feature representation: The bottom layer shows four stimuli: "red ink" (color), "blue ink" (color), "RED" (word), and "BLUE" (word). The color and word features are labeled "colors" and "words" respectively.

Verbal response: The top layer shows two verbal responses: "red" (color) and "blue" (word). The color and word responses are labeled "Verbal response" and "Control (PFC)" respectively.

Conflict monitoring (ACC): A central box labeled "Conflict monitoring (ACC)" receives input from the verbal response and the control (PFC) regions. It sends output to the verbal response and the control (PFC) regions.

Connections: The diagram shows connections between the stimulus features and the verbal responses. The "red ink" stimulus is connected to the "red" verbal response. The "blue ink" stimulus is connected to the "blue" verbal response. The "RED" stimulus is connected to the "red" verbal response. The "BLUE" stimulus is connected to the "blue" verbal response. The "red ink" and "RED" stimuli are connected to the "blue" verbal response. The "blue ink" and "BLUE" stimuli are connected to the "red" verbal response. The "red ink" and "blue ink" stimuli are connected to the "red" verbal response. The "RED" and "BLUE" stimuli are connected to the "blue" verbal response.



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