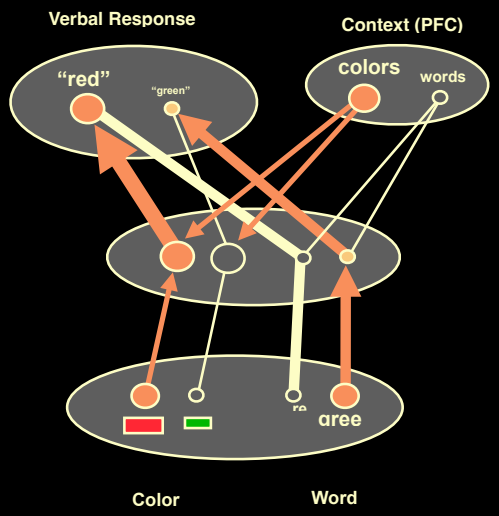
Adaptive Gating and Control

Guided Activation Theory

Cohen & Servan-Schreiber (1992); Miller & Cohen (2001)



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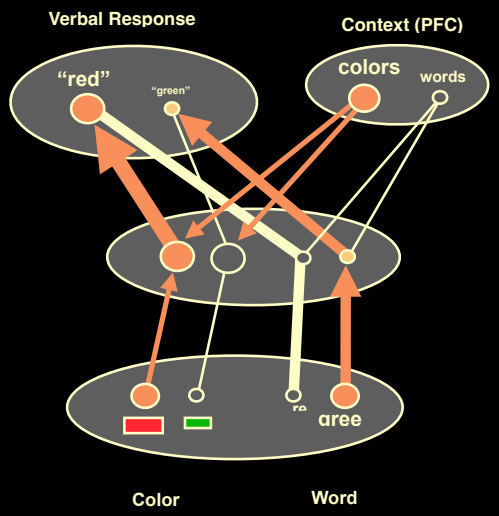
- **Representations in PFC bias decision processes to establish a task set: mappings between input, memory, and output representations**
  - **Ties control of decision making to working memory, attention and inhibition**



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- **Accounts for psychological / behavioral data:**

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  - **Stroop inhibition paradigm** (Cohen et al., 1990; Phaf et al., 1990)
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  Neuropsychological deficits in such tasks

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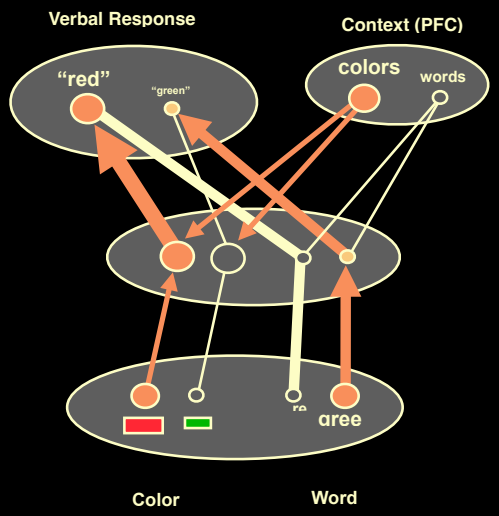

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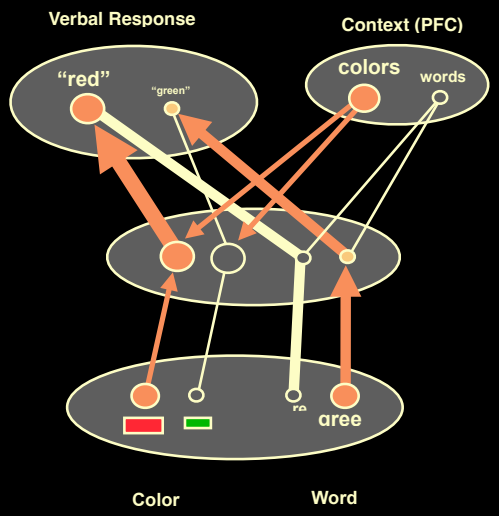
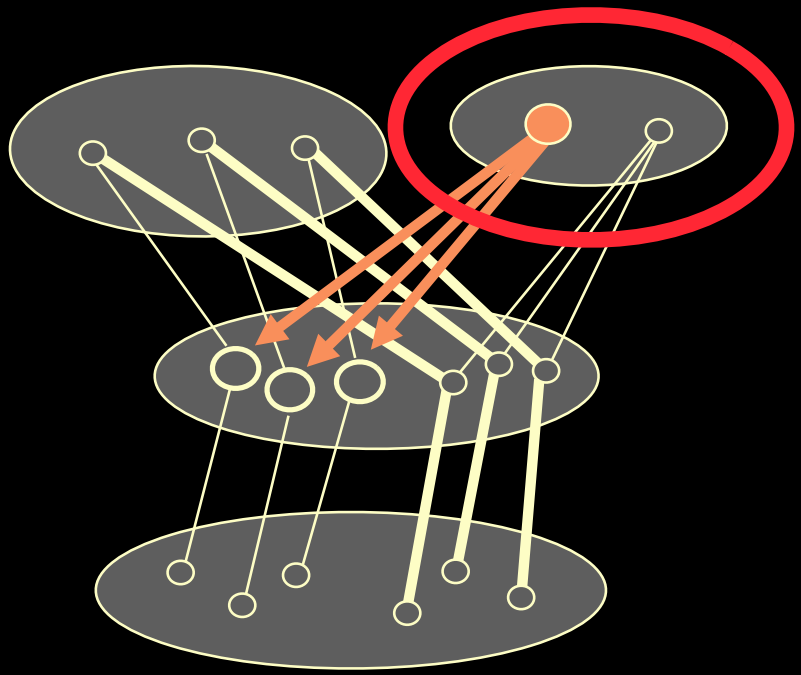


- **Accounts for neurobiological data**
  - **Single unit recordings from PFC in non-human primates**

    (e.g., Miller, Erickson & Desimone, 1996; Rainer et al., 1998; Asaad, Rainer & Miller, 2000)
  - **Neuroimaging findings in humans**

    (e.g., e.g., Jonides & Smith, 1993; Barch et al., 1998; MacDonald et al., 2001; Yeung et al., 2006)

Limitation



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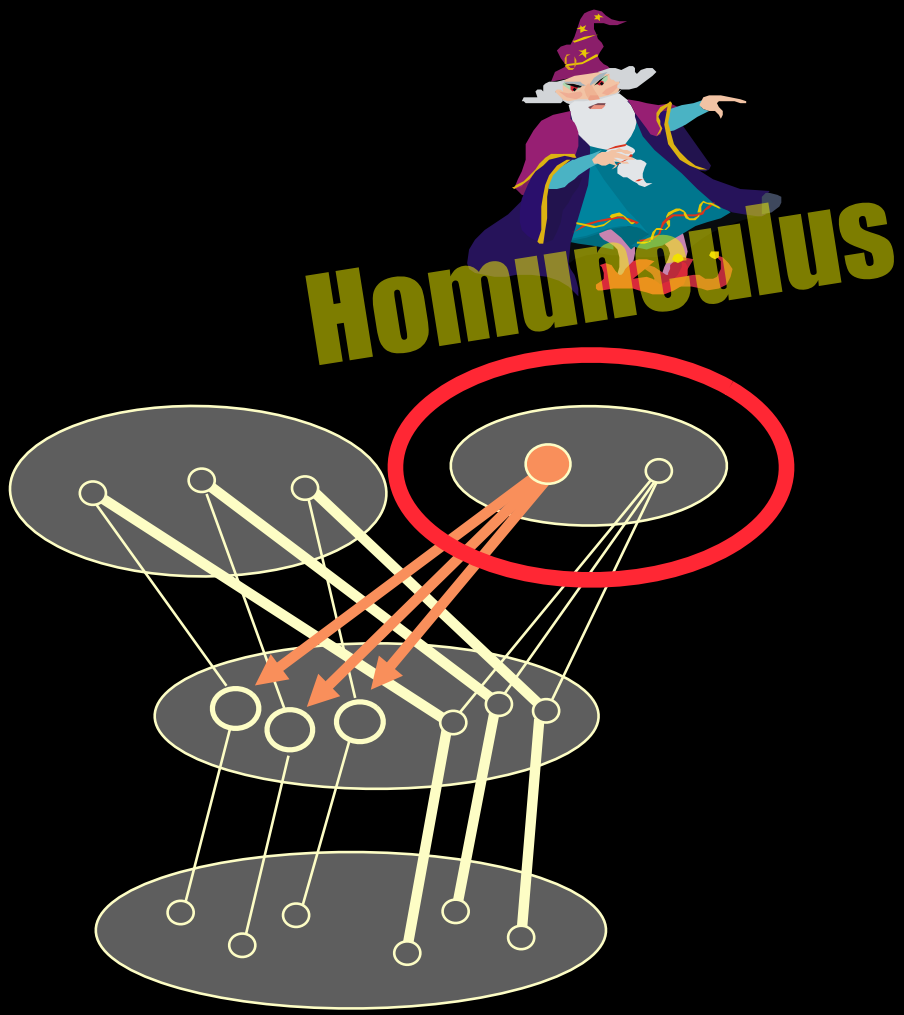

Challenges

- How are control representations maintained w/in PFC?
- How are control representations updated?
- How are adjustments made in the degree of control?
- How do representations develop, and what do they look like?

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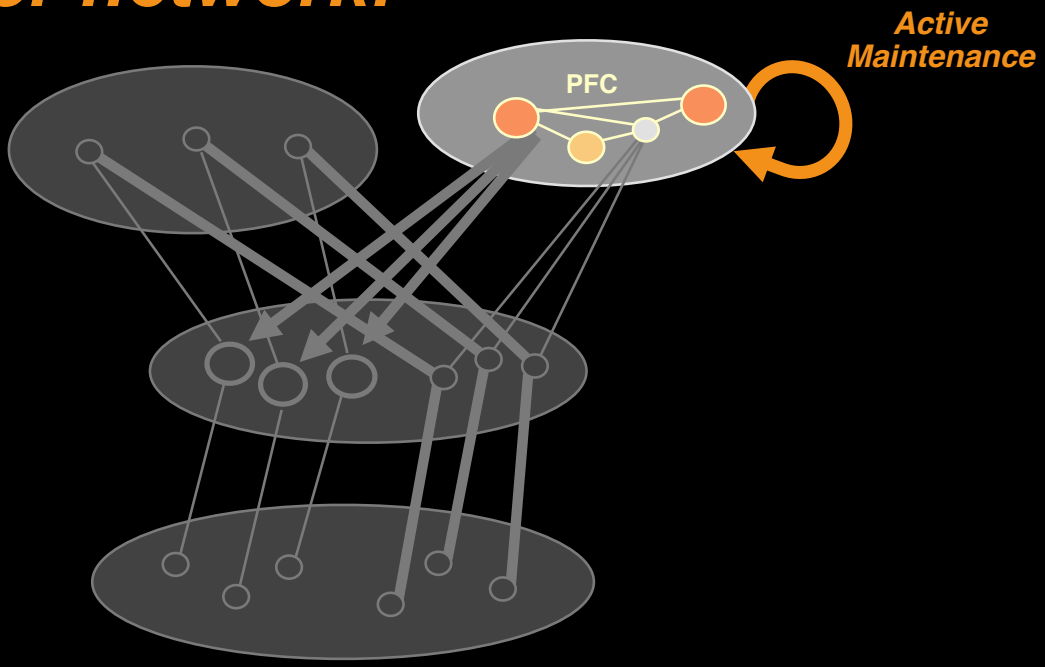
Attractor network:



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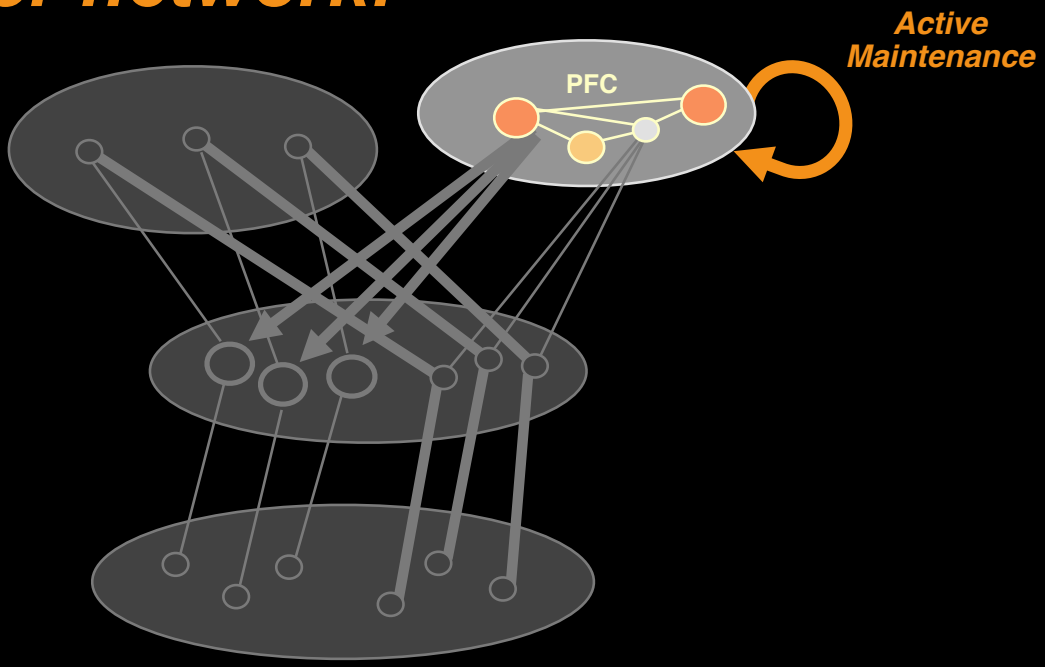
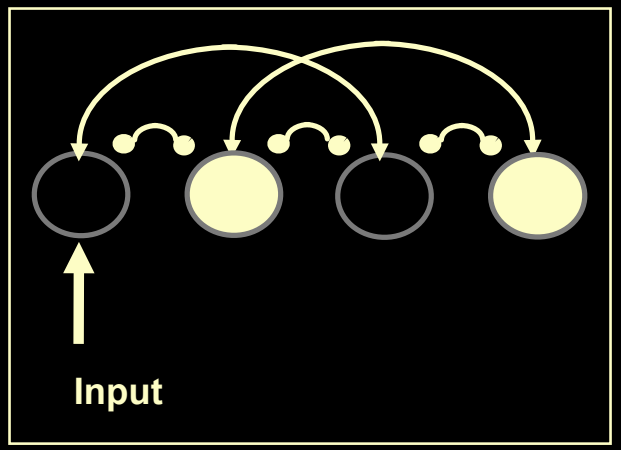


but there's a problem…

Attractors



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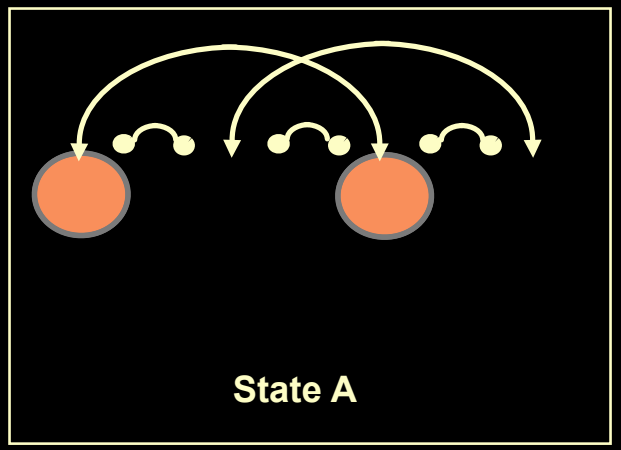

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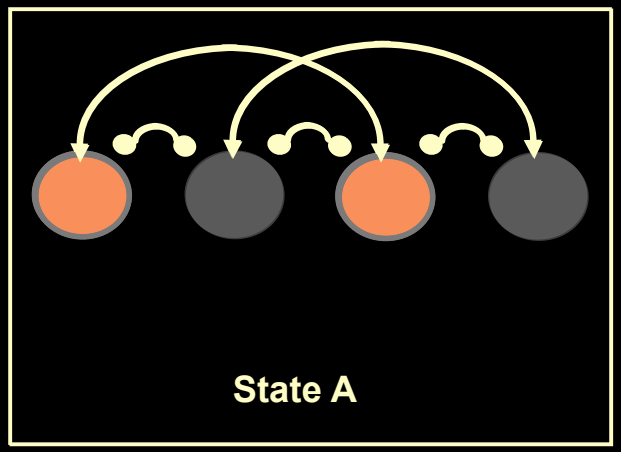

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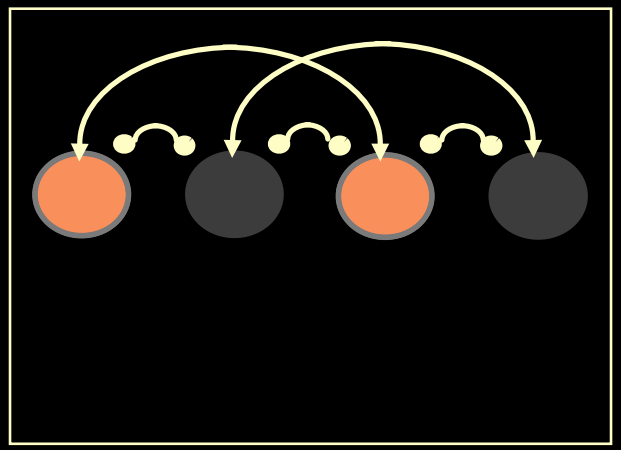
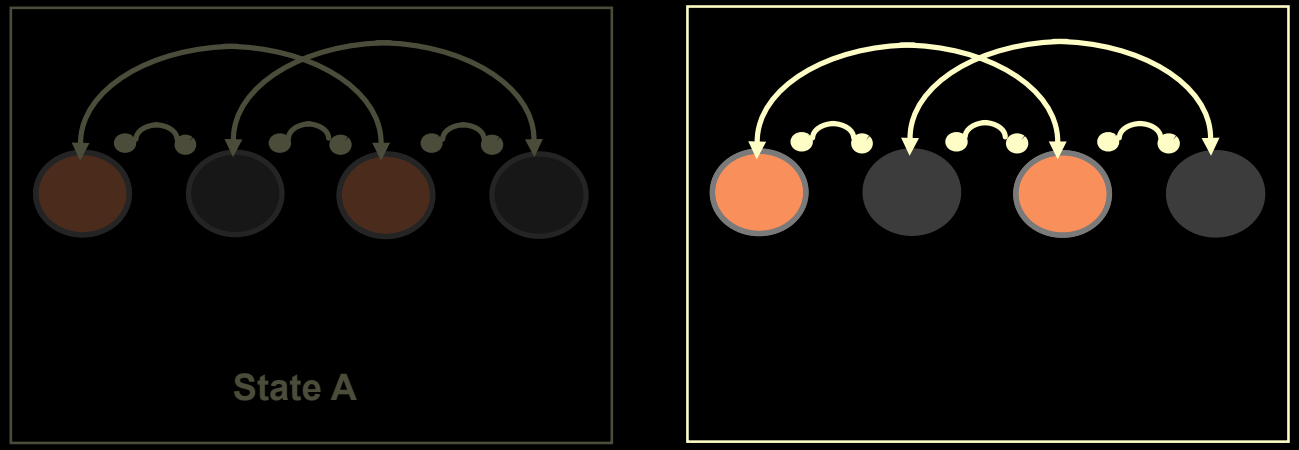


Attractors and Interference



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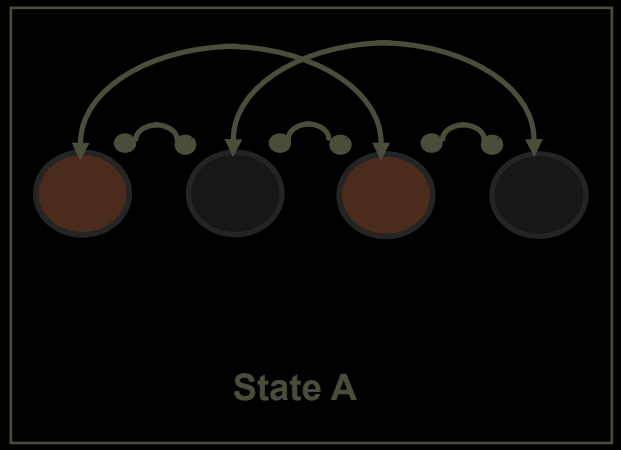

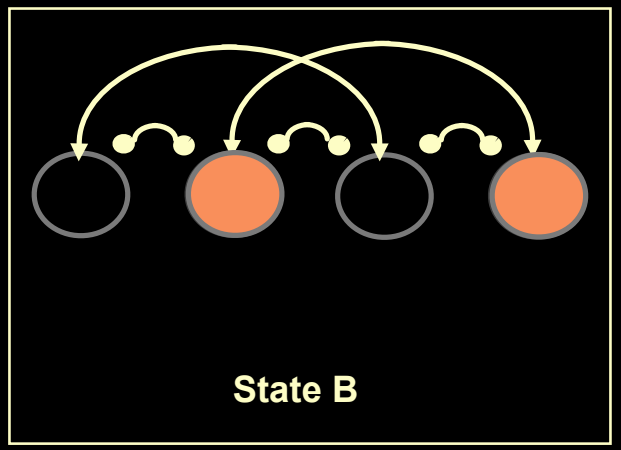

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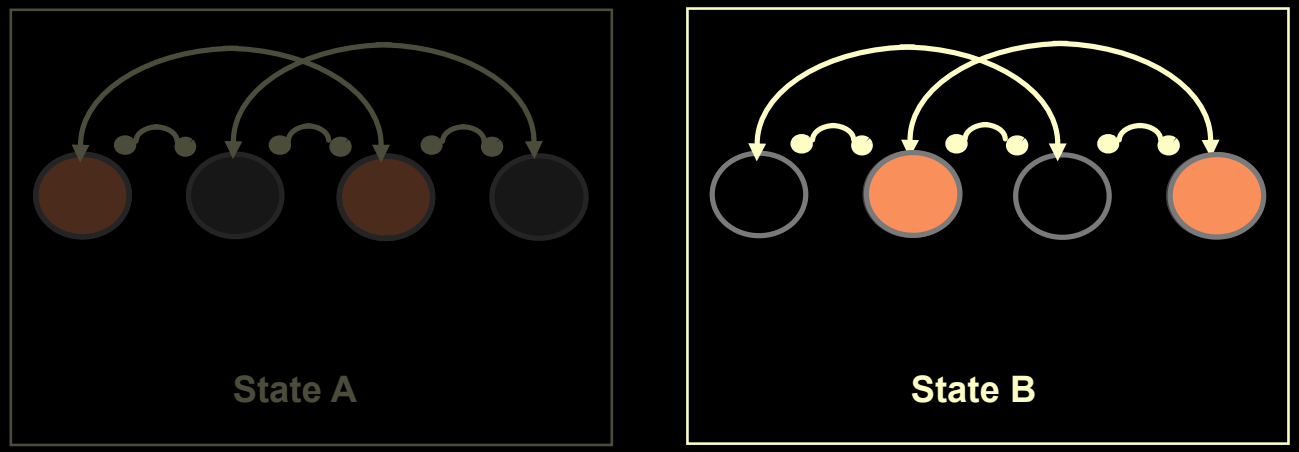

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  - strong attractor: robust maintenance, but hard to switch
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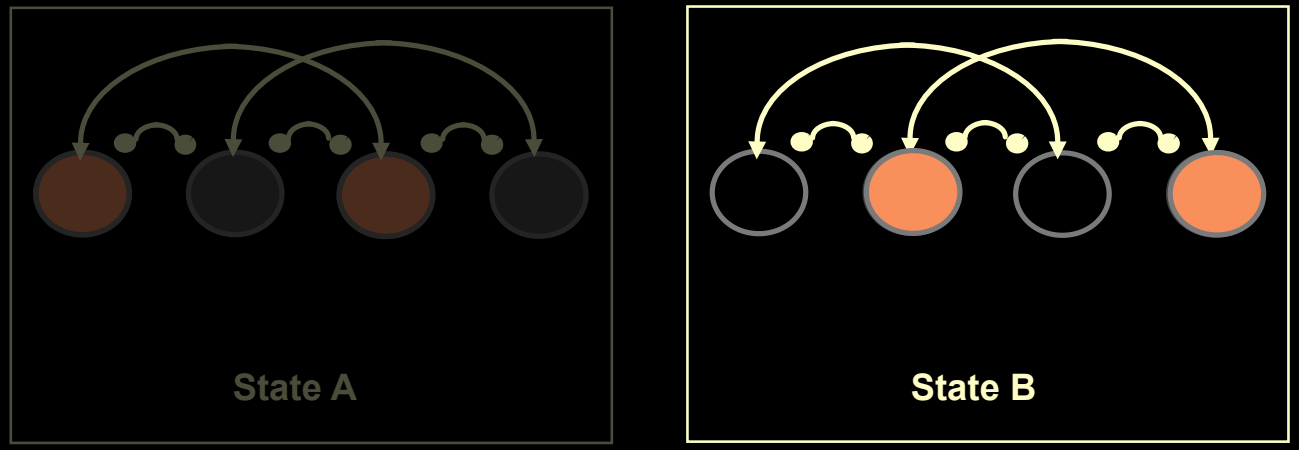

- **Flexibility-Stability tradeoff:**
  - strong attractor: robust maintenance, but hard to switch ➡ *perseveration*
  - weak attractor: greater flexibility, but too subject to interference ➡ *distractibility*

Hallmarks of frontal lobe damage:

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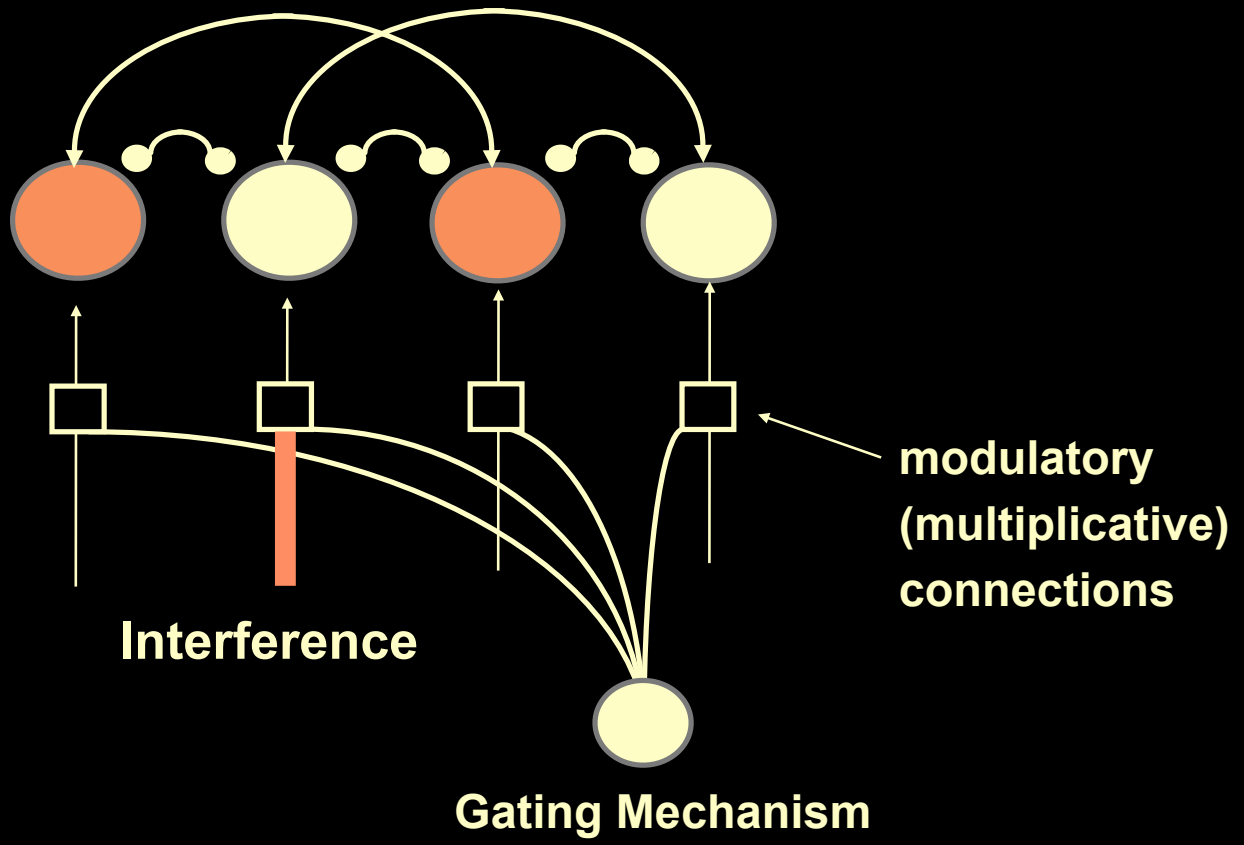

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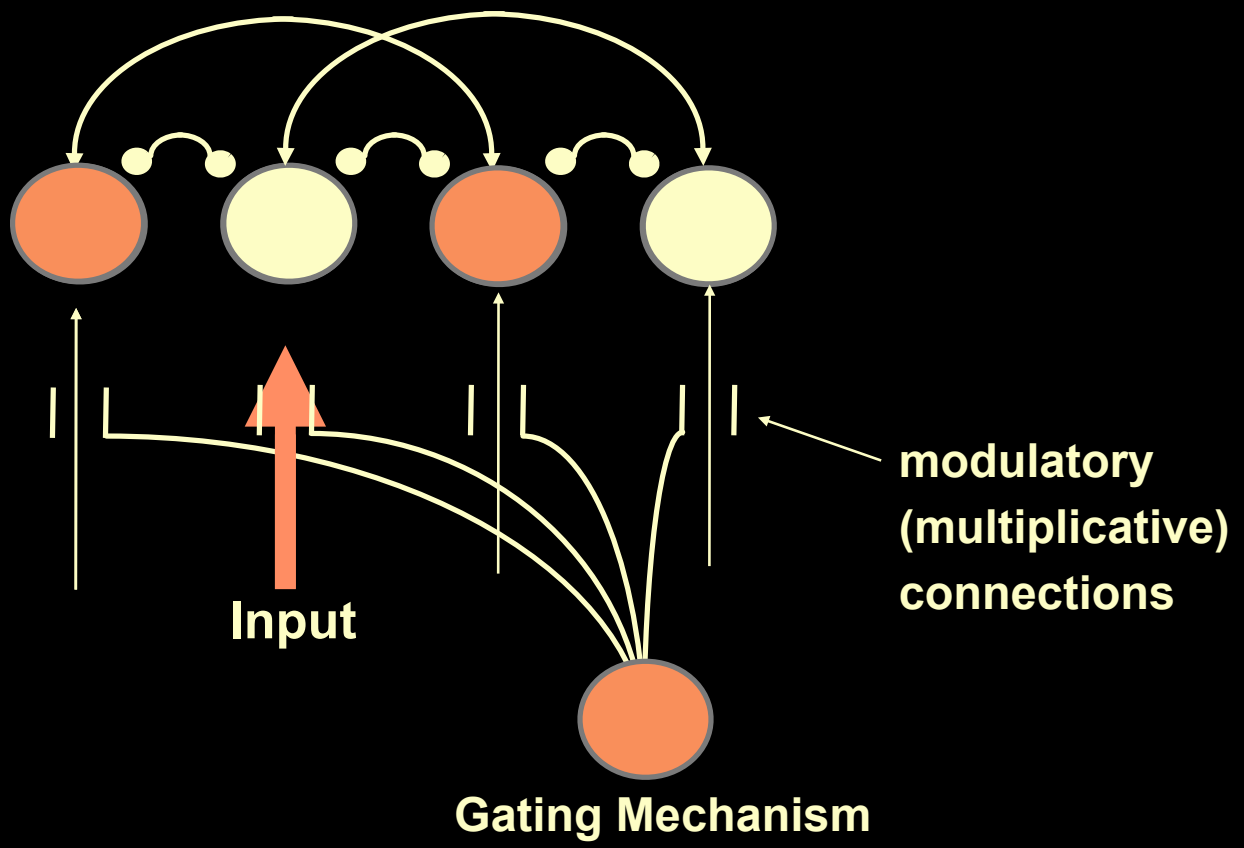

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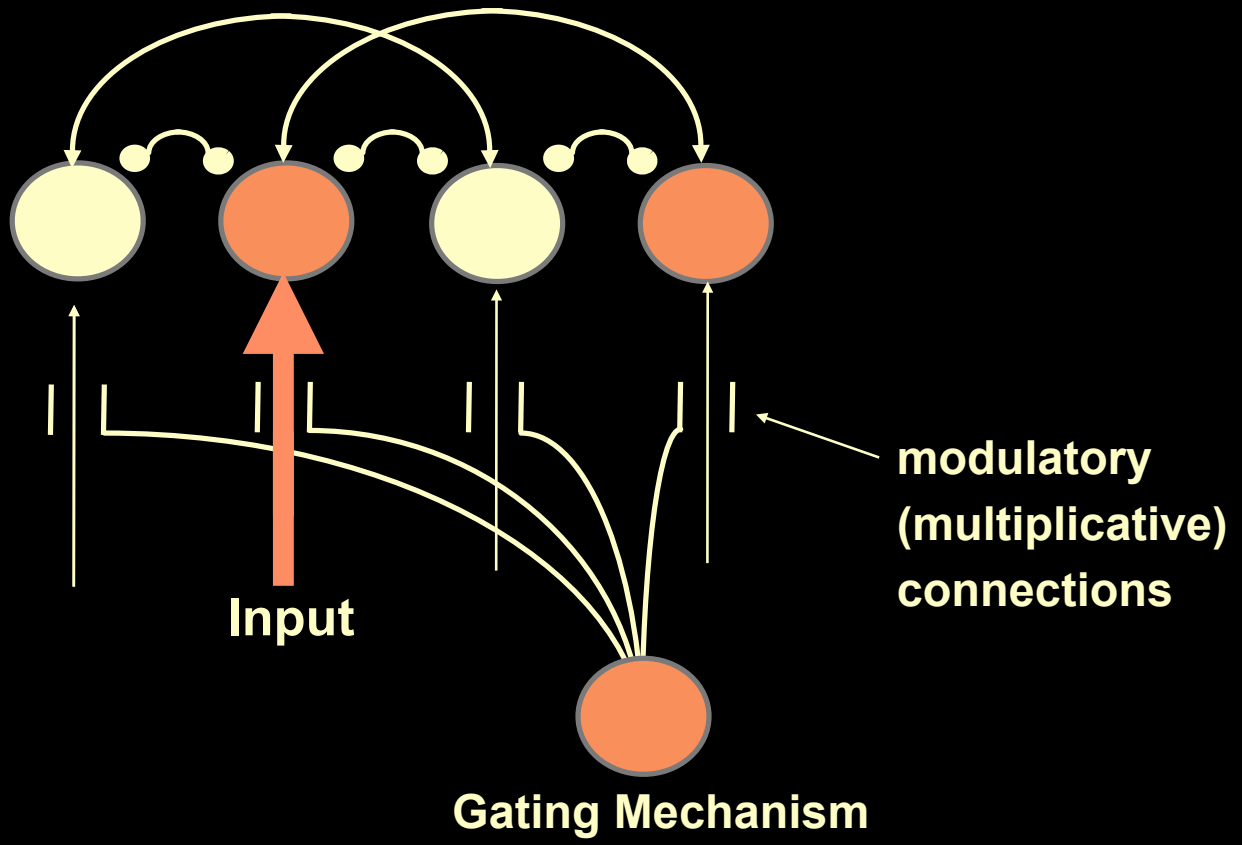

Dopamine as a Gating Mechanism

- **Modulatory effects of DA**

  Neurophysiology: modulates neural responsivity

  (Chiodo & Berger, 1986; Seamans & Yang, 2004)

  Modeling: changes in gain of activation function

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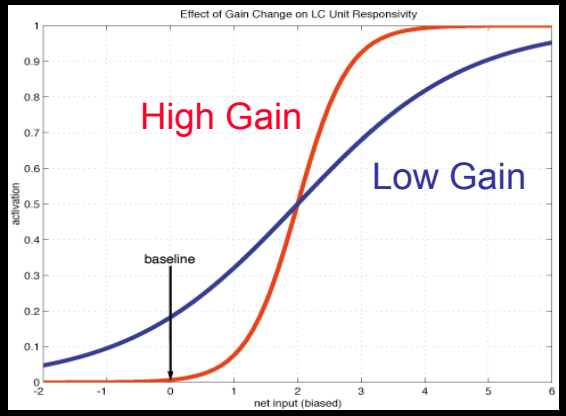

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  Rapid, stimulus-specific responses *(Shultz, 1992)*

  Appropriate timing:
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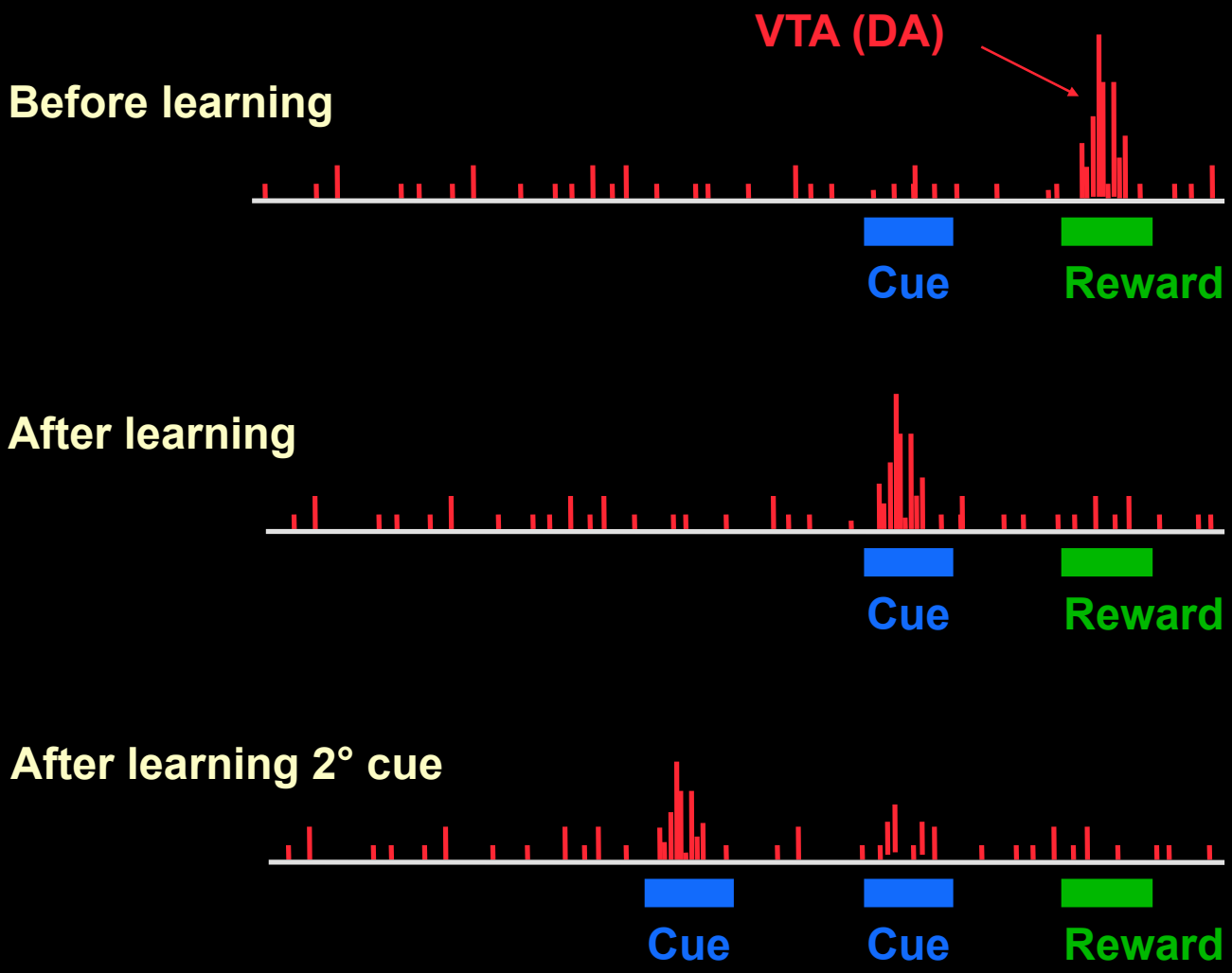
Timing of Phasic DA Signal



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⇒ **DA acts as a "gate" regulating access to active memory**

The Return of the “Homunculus”

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- Who controls the controller? (i.e., the gating signal)

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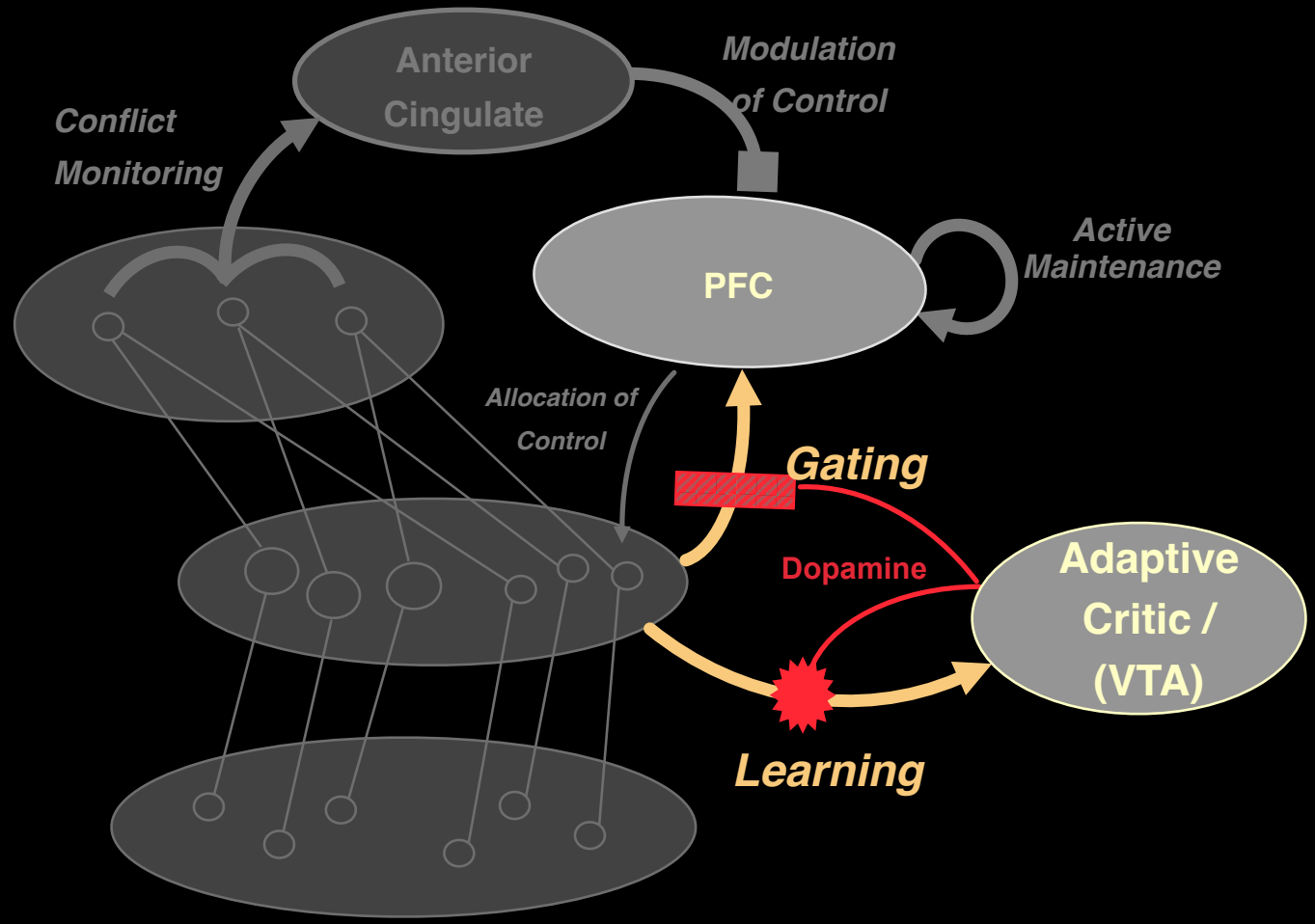
Adaptive Updating of Control

Braver & Cohen (2000)



Computational Validation

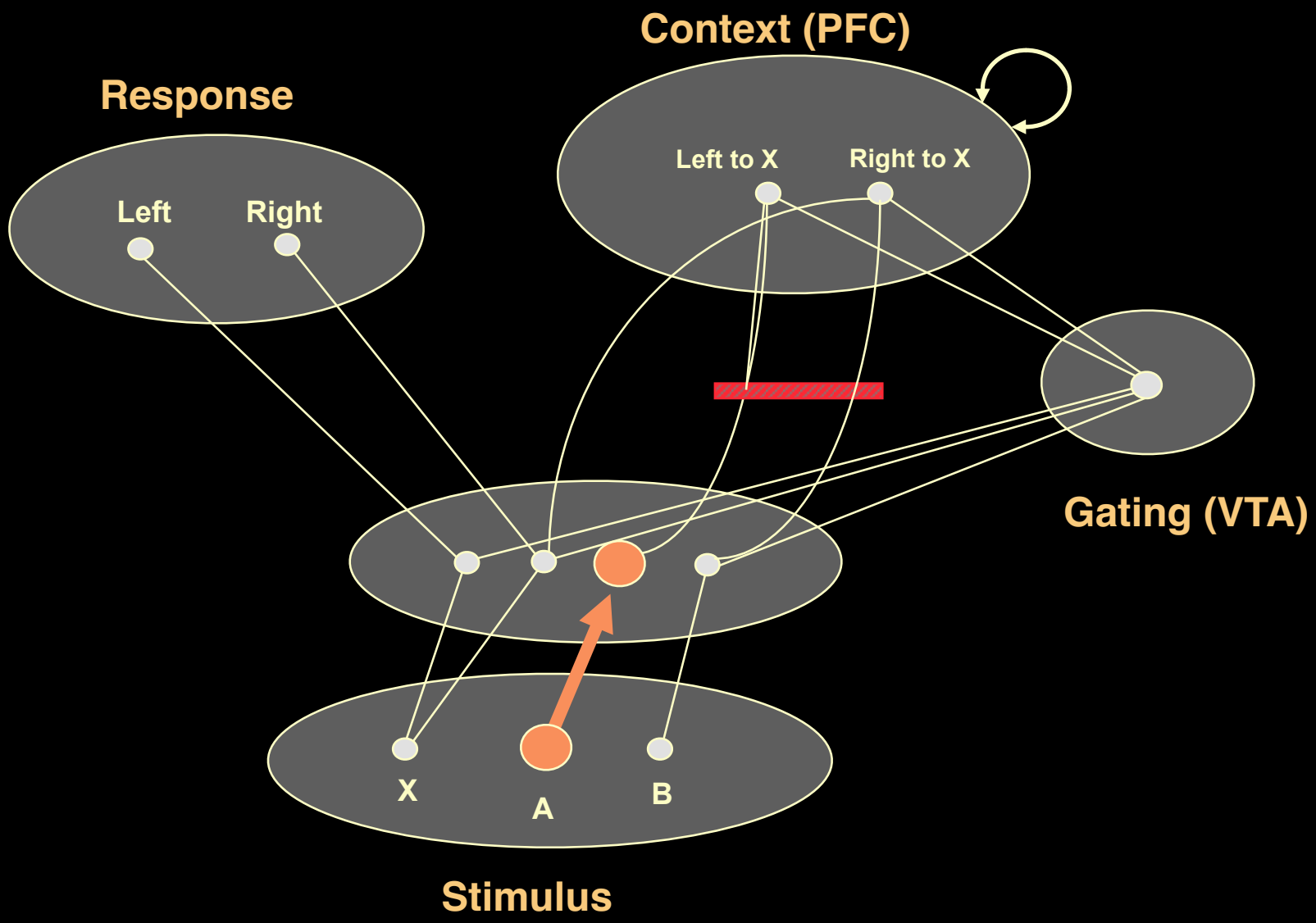
AX-CPT: Canonical context dependent task

Press left button whenever an X follows an A, otherwise, press the right button:

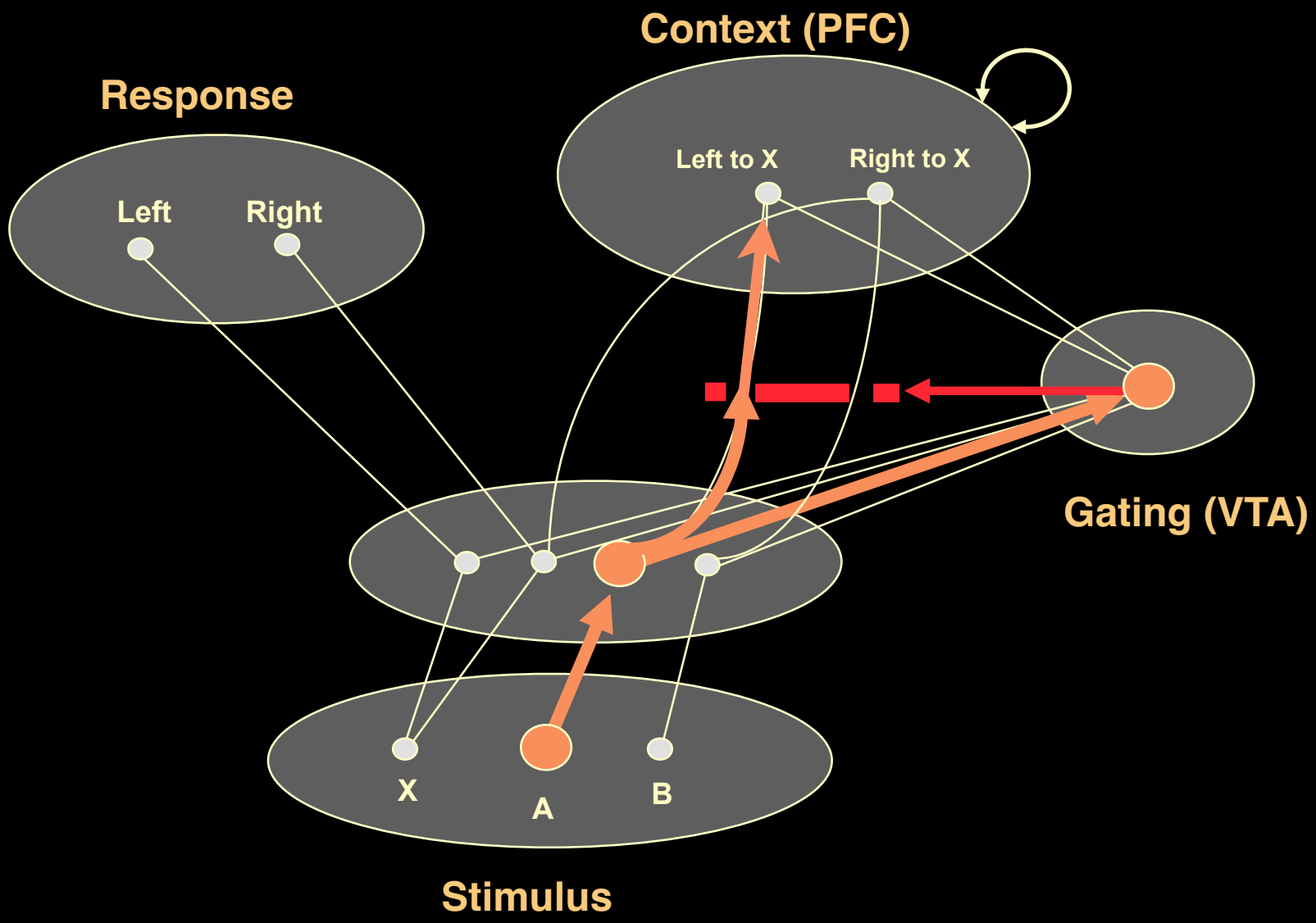
R...	X...	M...	A...	X...
Right	Right	Right	Right	Left

Response to an X depends on context provided by previous stimulus

AX-CPT: Cue


Context (PFC)
Response
Left to X
Right to X
Left
Right
Gating (VTA)
X
A
B
Stimulus

AX-CPT: Cue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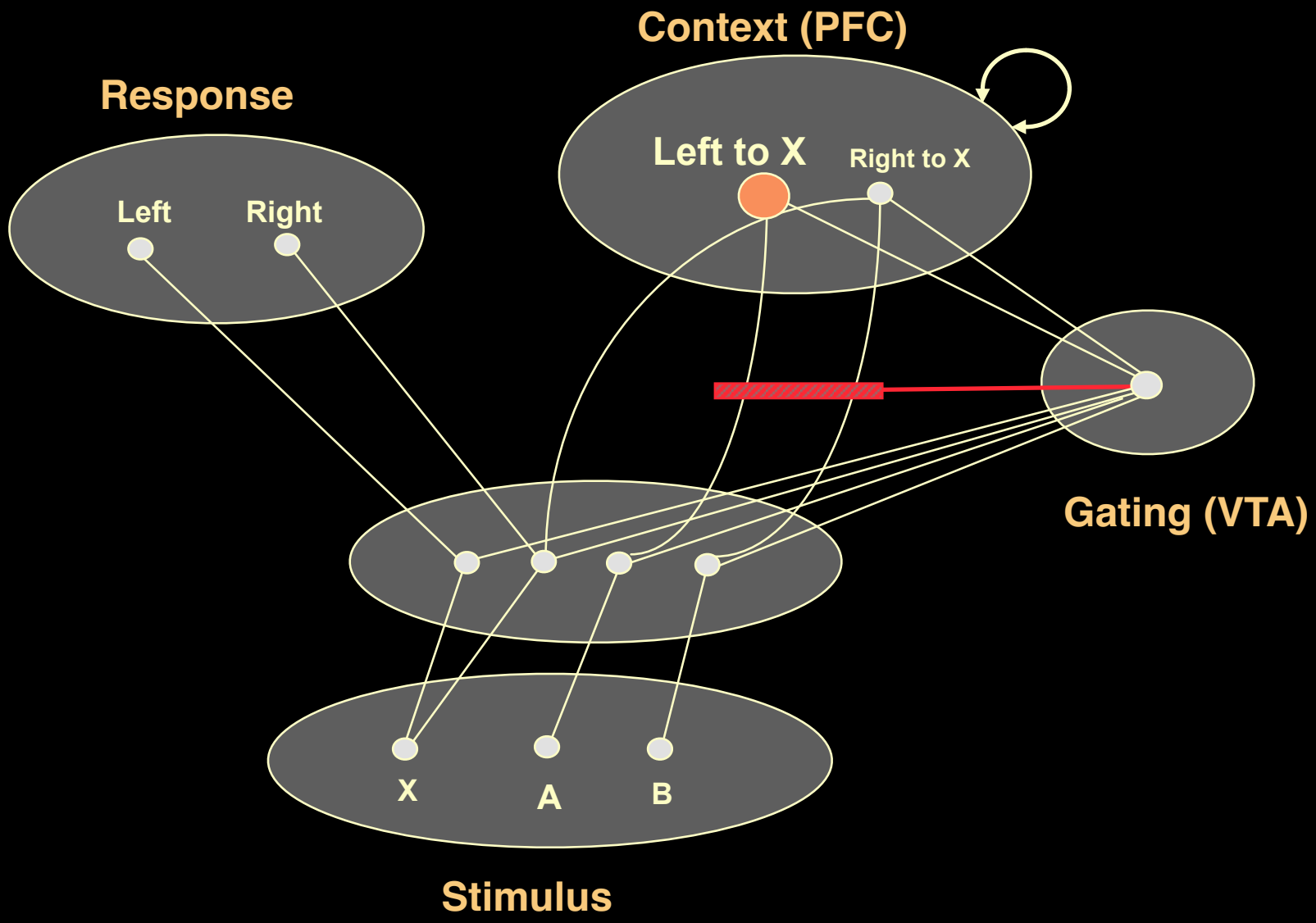
AX-CPT: Delay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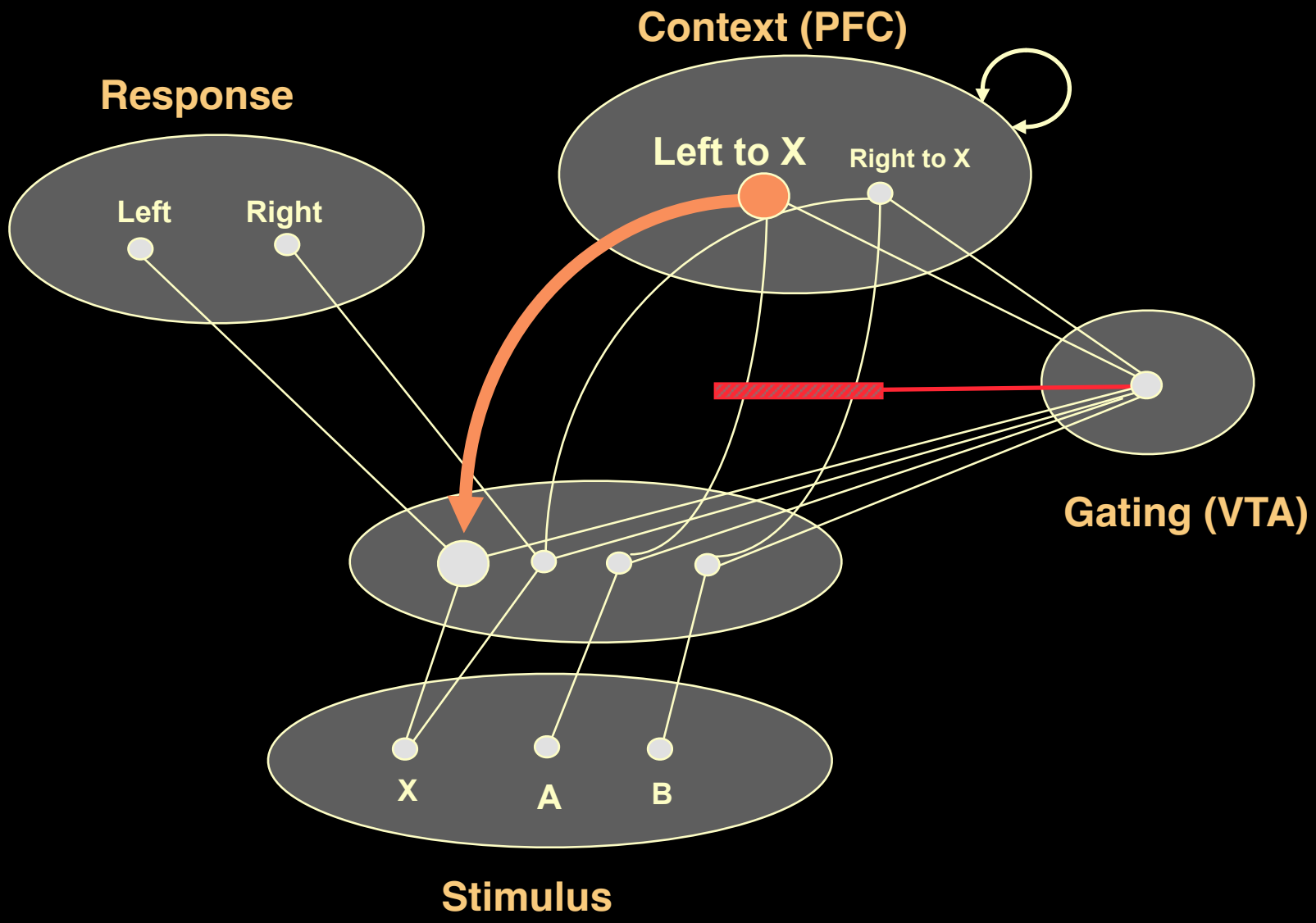
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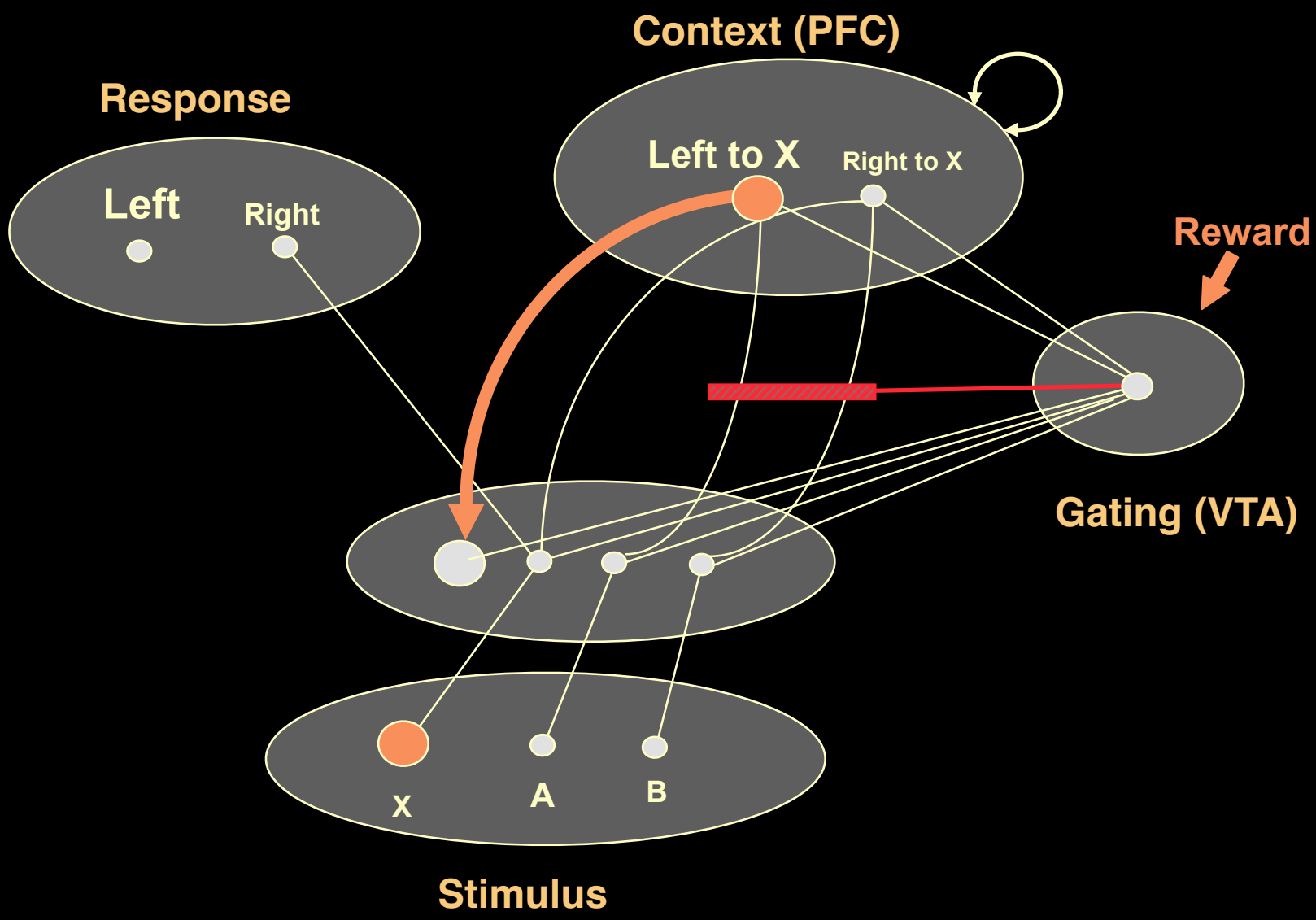
AX-CPT: Target



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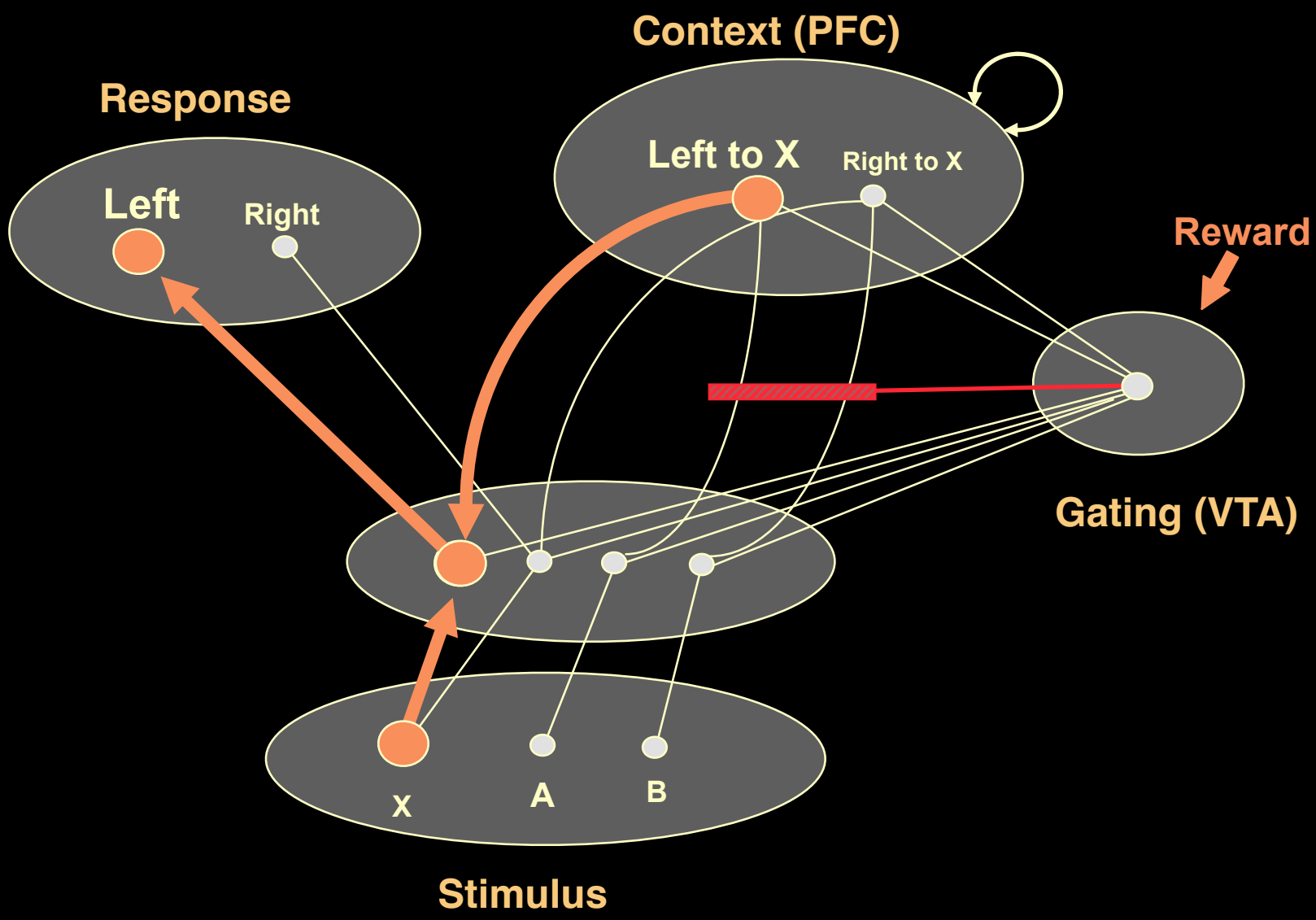

Timing of the Gating Signal as a Function of Training

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