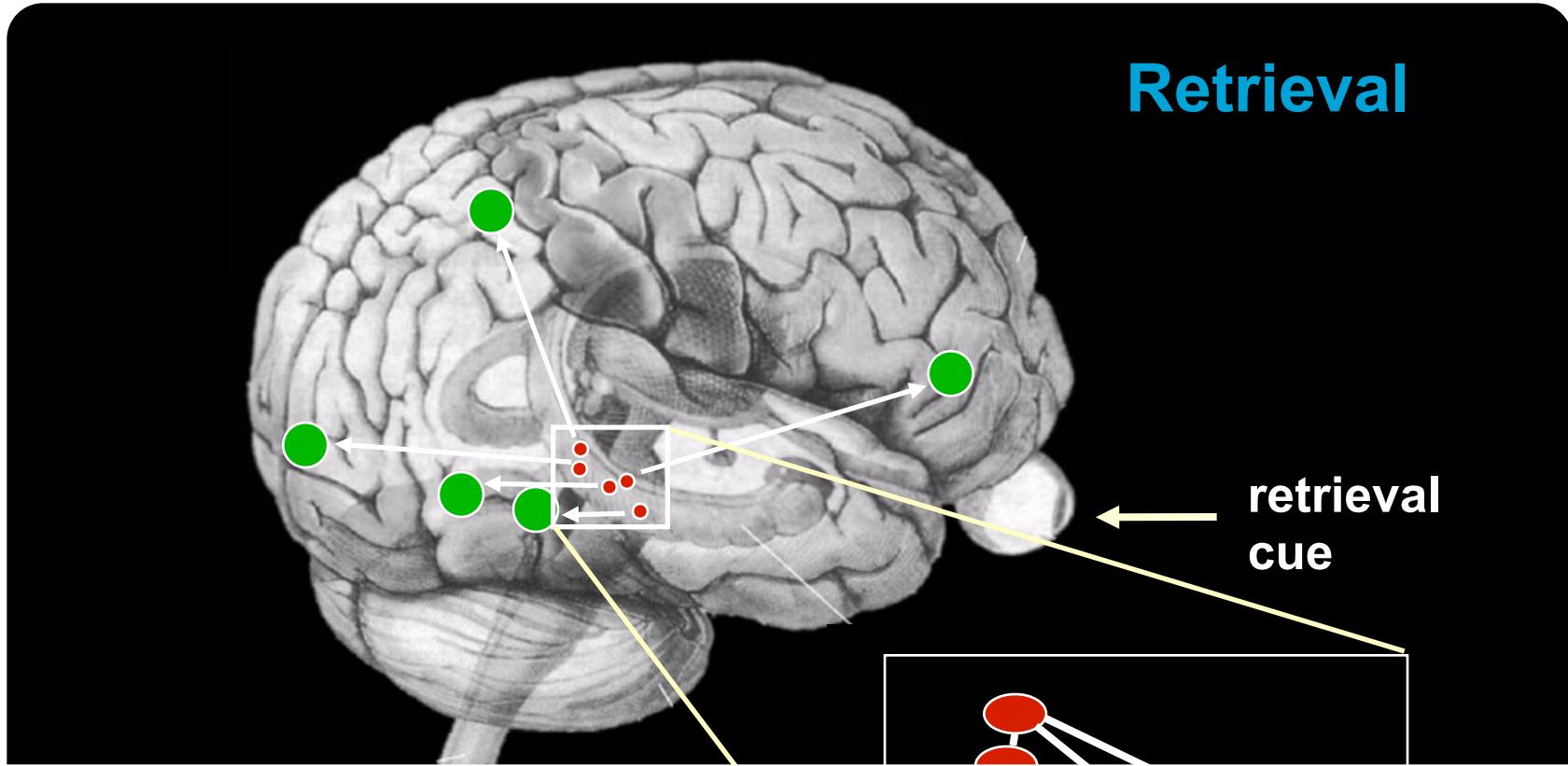


# Outline

---

- Principles of Episodic Retrieval
  - Pattern Completion and Reinstatement
  - Consolidation, redux
  - Cue-dependent Nature of Retrieval
- Recognition Memory

# Event Remembering: Cortical Reinstatement



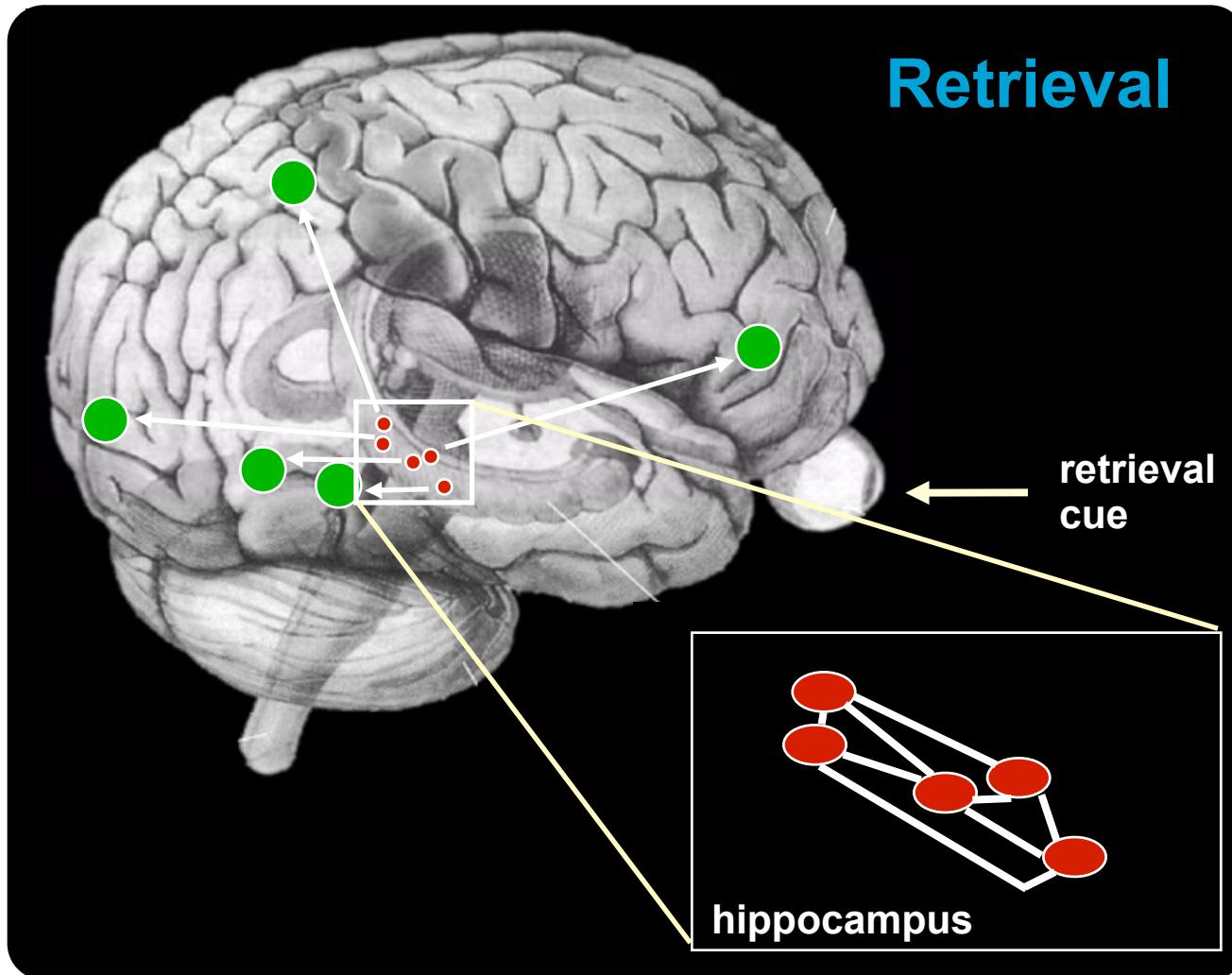
## Remembering as *Reinstatement*

- patterns of activation in perceptual and conceptual cortical areas at encoding are reinstated when remembering those perceptual/conceptual event details

# Event Remembering: Cortical Reinstatement

## Key Points:

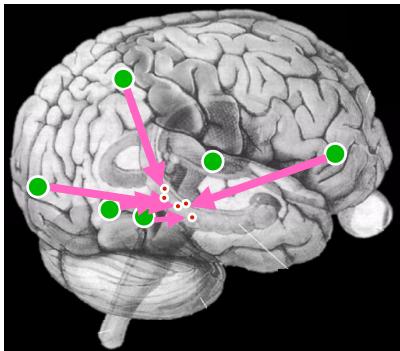
- Reinstatement is **reactivation of cortical patterns** that were present during **encoding**
- Emerges via **hippocampal-cortical interactions** at retrieval



# **Event Remembering: Cortical Reinstatement**

- Insights from **humans** (neuroimaging)
  - Remembering percepts
  - Remembering thoughts
- Insights from **monkeys** (direct recordings)
  - The role of the MTL in associative memory & reinstatement

# Remembering Percepts: Cortical Reinstatement in Humans



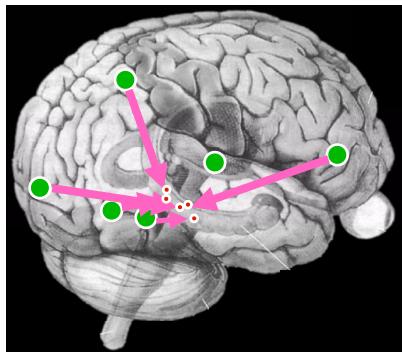
Vinny

time

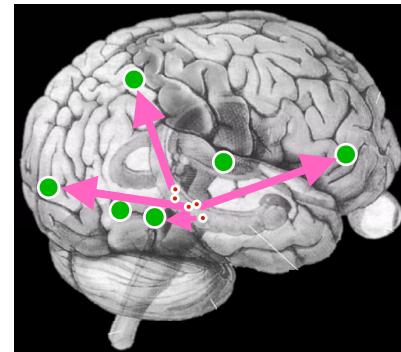


Encoding

# Remembering Percepts: Cortical Reinstatement in Humans



Vinny



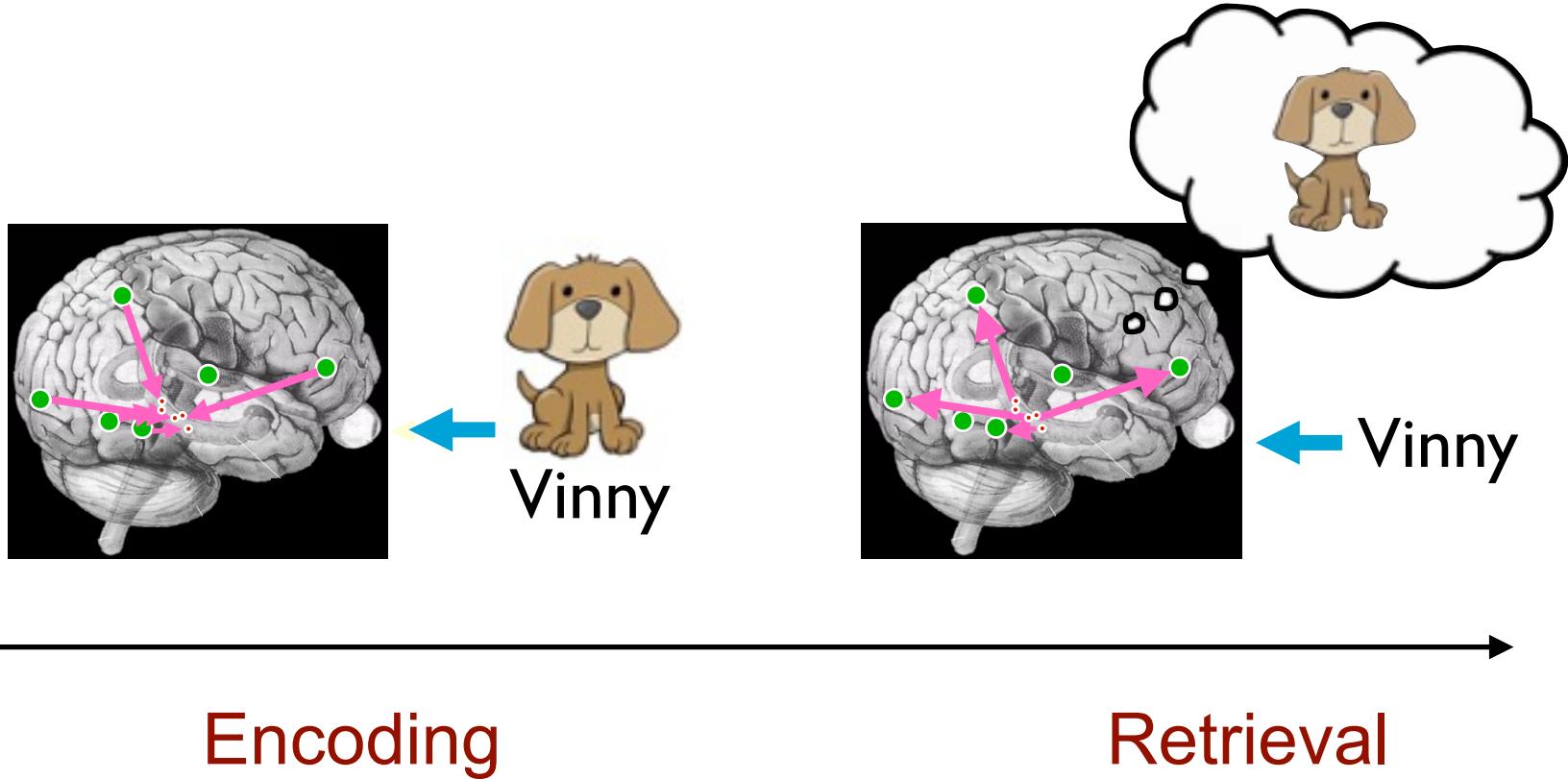
time



Encoding

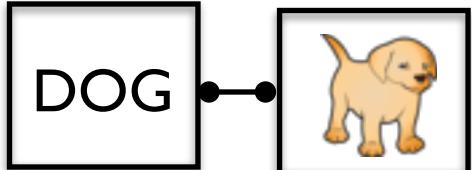
Retrieval

# Remembering Percepts: Cortical Reinstatement in Humans



# Remembering Percepts: Cortical Reinstatement in Humans

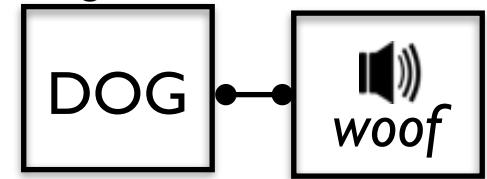
Encoding/Perceive:



Encoding

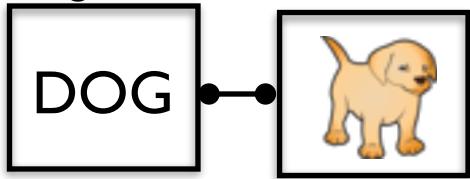
- visual word paired with picture or sound

Encoding/Perceive:

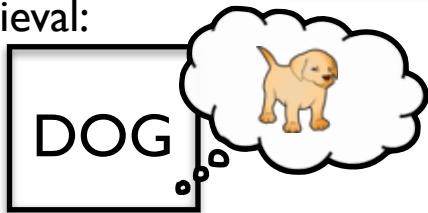


# Remembering Percepts: Cortical Reinstatement in Humans

Encoding/Perceive:



Retrieval:



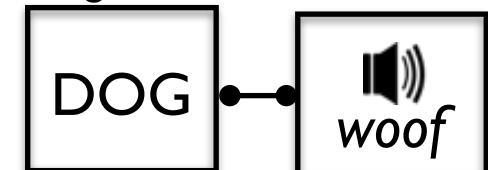
Encoding

- visual word paired with picture or sound

Retrieval

- visual word
- remember picture or sound

Encoding/Perceive:

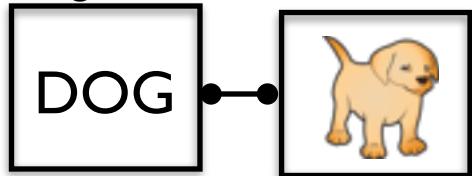


Retrieval:

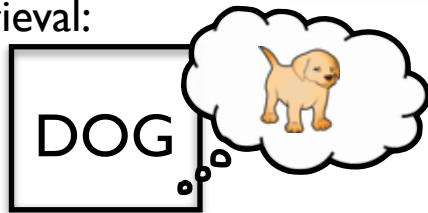


# Remembering Percepts: Cortical Reinstatement in Humans

Encoding/Perceive:



Retrieval:



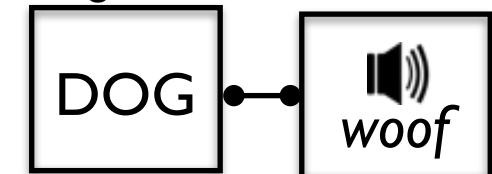
Encoding

- visual word paired with picture or sound

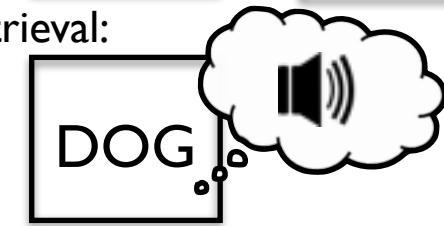
Retrieval

- visual word
- remember picture or sound

Encoding/Perceive:

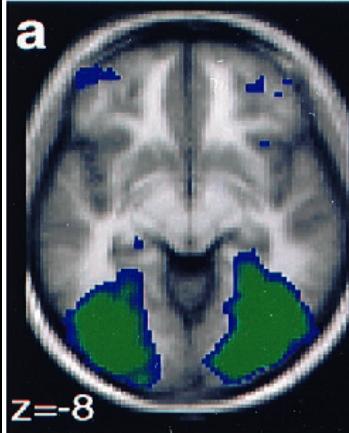


Retrieval:

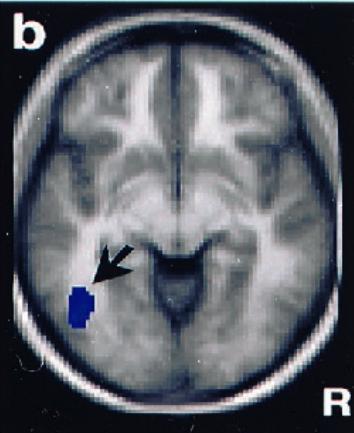


## PICTURES

Perceive



Retrieve

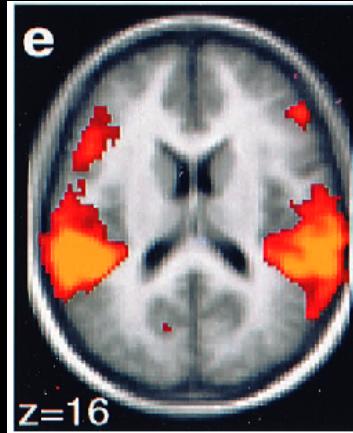


(Wheeler et al. 2000)

- visual cortex

## SOUNDS

Perceive



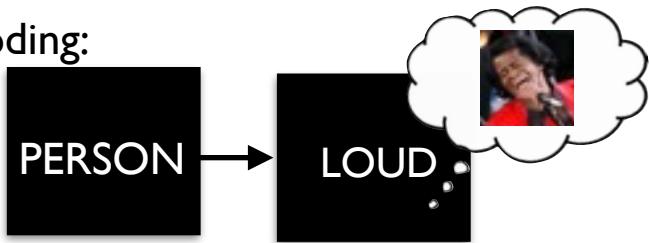
Retrieve



- auditory cortex

# Remembering Thoughts: Cortical Reinstatement in Humans

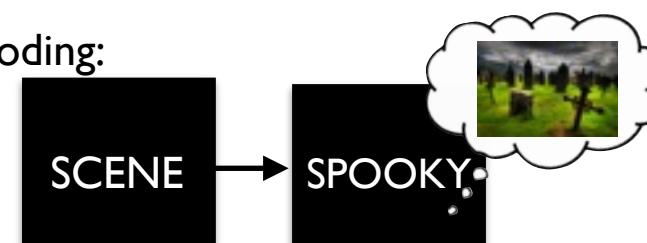
Encoding:



Encoding

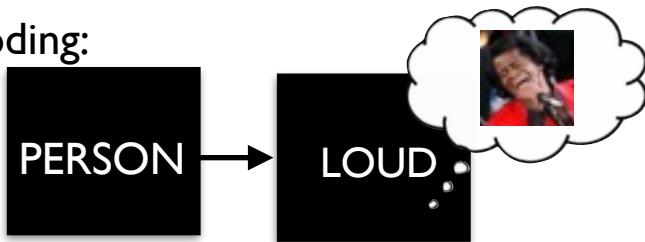
- visual word
- imagine person or scene

Encoding:

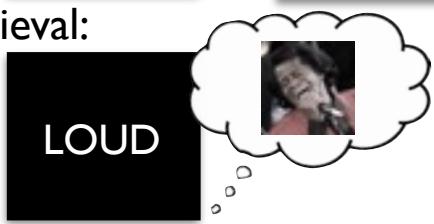


# Remembering Thoughts: Cortical Reinstatement in Humans

Encoding:



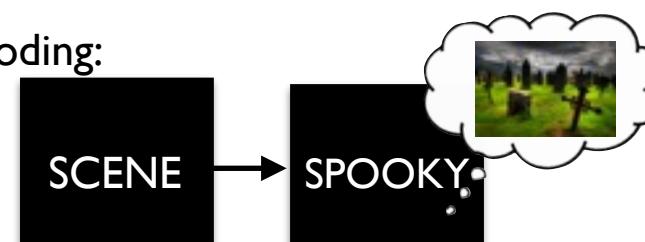
Retrieval:



**Encoding**

- visual word
- imagine person or scene

Encoding:



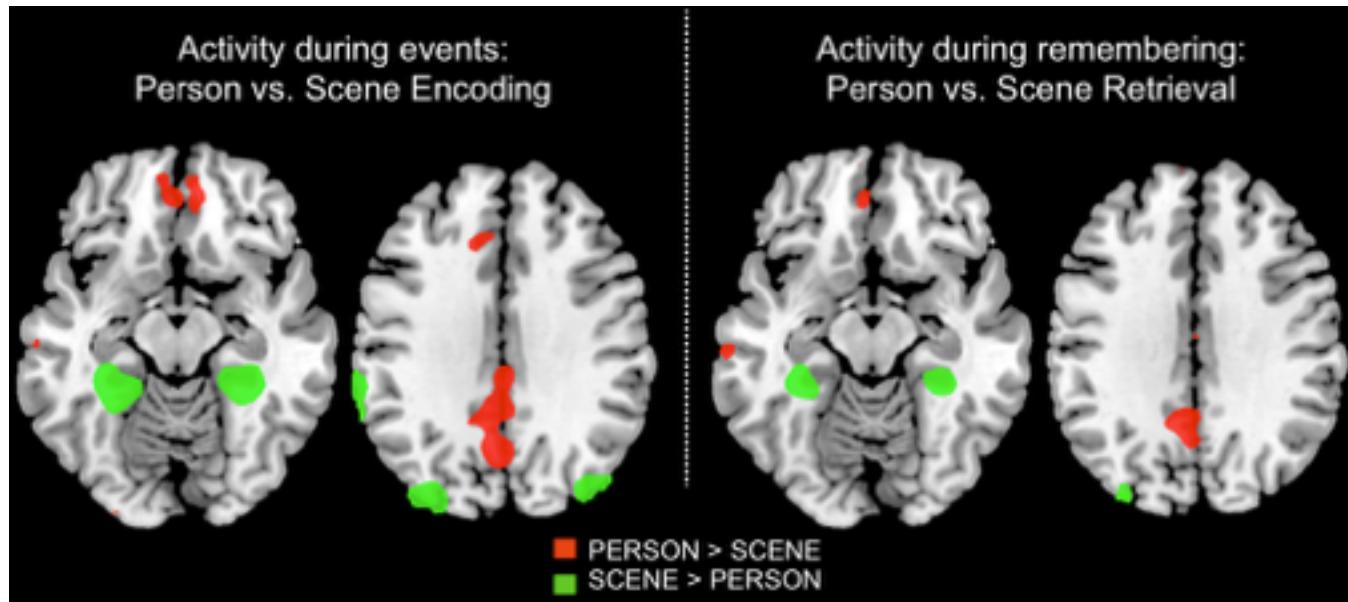
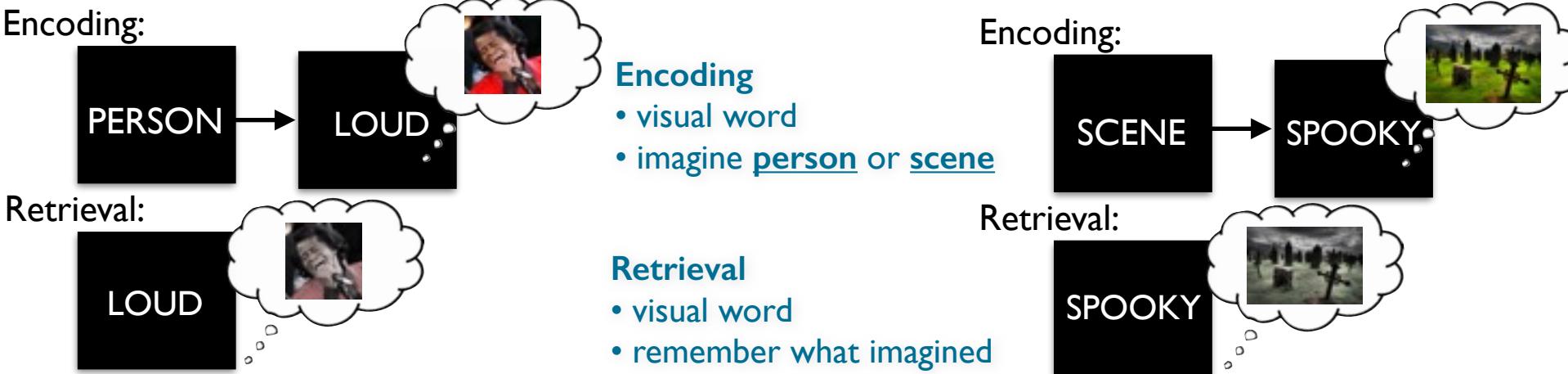
Retrieval:



**Retrieval**

- visual word
- remember what imagined

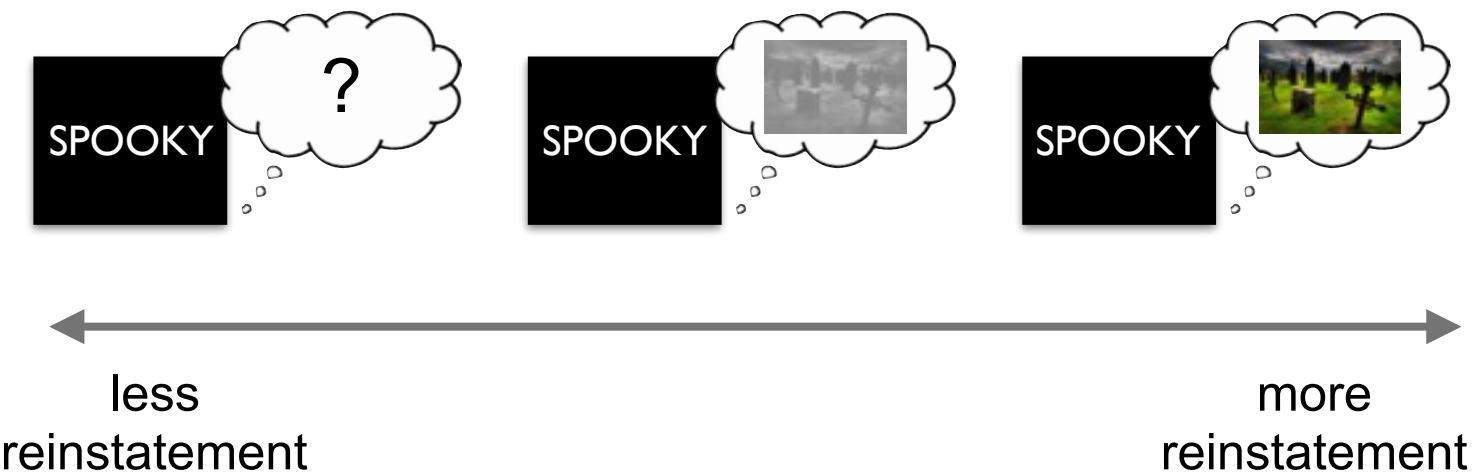
# Remembering Thoughts: Cortical Reinstatement in Humans



# Event Remembering: Quantifying Cortical Reinstatement

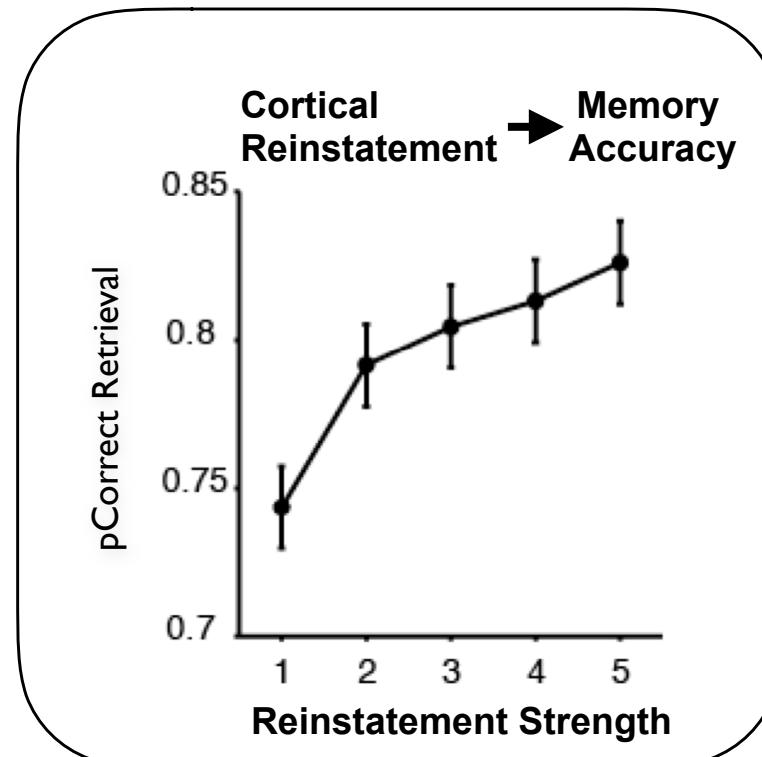
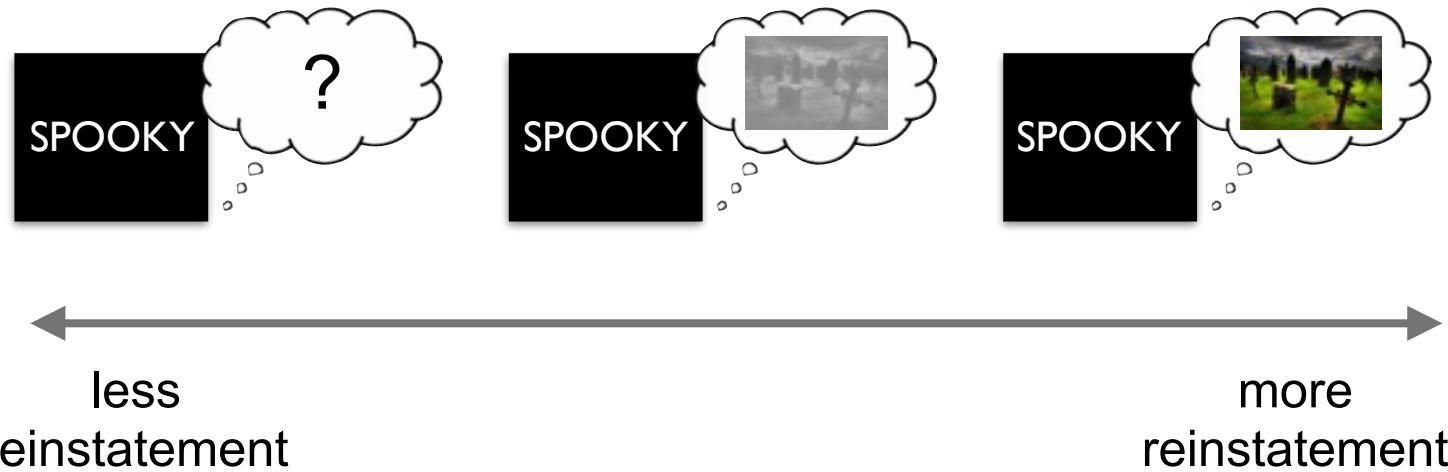
- Quantify ‘strength’ of cortical reinstatement and relate to behavior.

## Retrieval:



# 'Strength' of Cortical Reinstatement: Correlates with Retrieval Accuracy

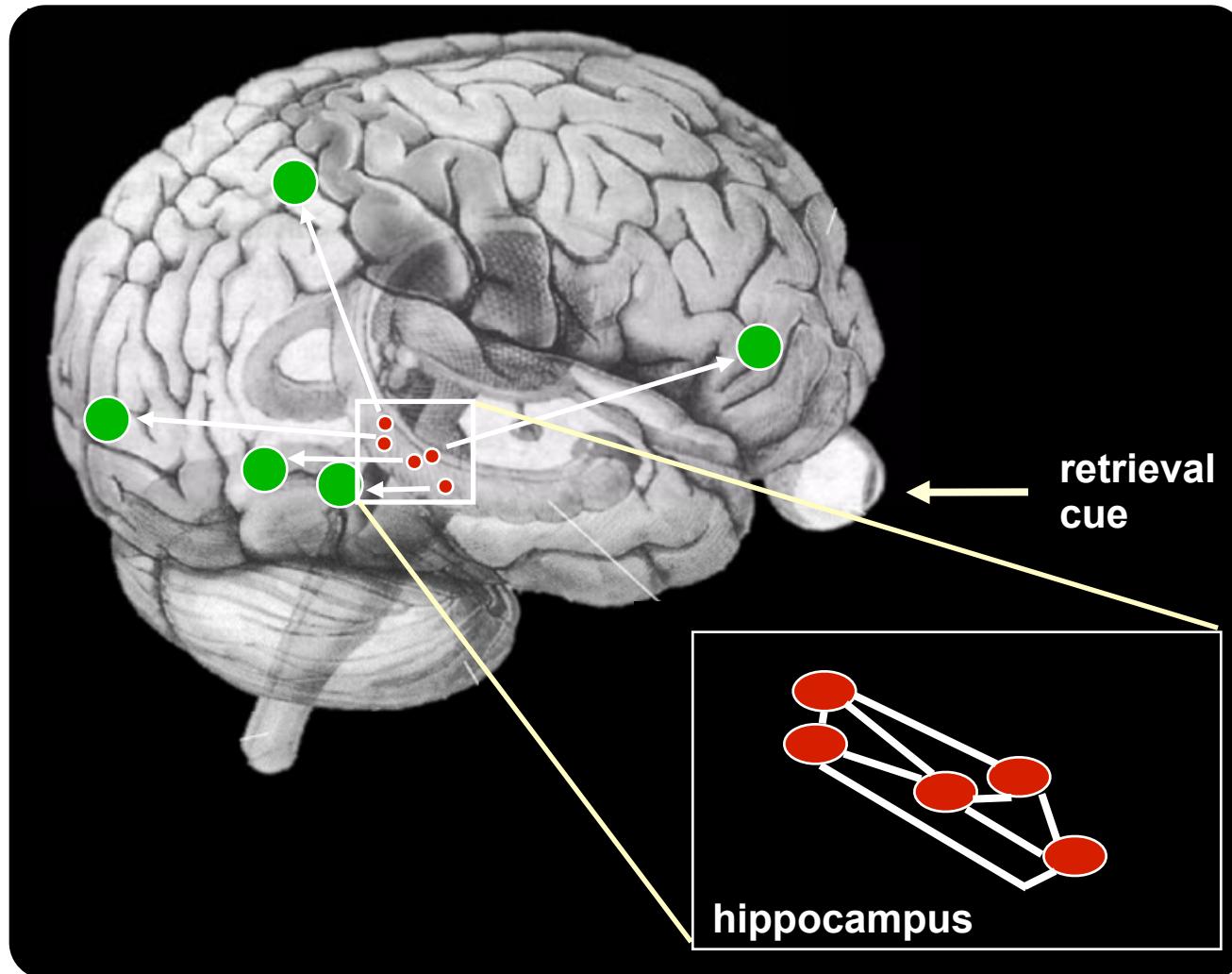
Retrieval:



# Event Remembering: Cortical Reinstatement

## Key Points:

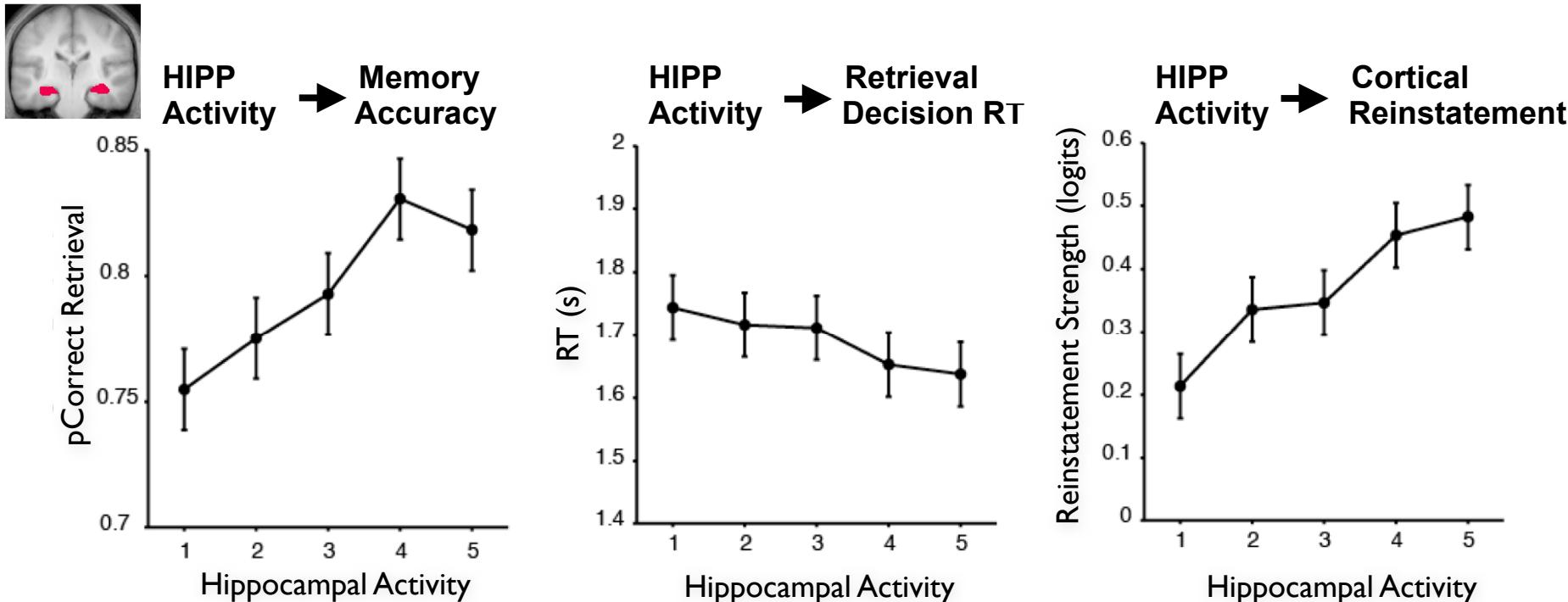
- Reinstatement is **reactivation of cortical patterns** that were present during **encoding**
- Emerges via **hippocampal-cortical interactions** at retrieval



# Event Remembering: Examining Role of Hippocampus

- Quantify ‘strength’ of cortical reinstatement and relate to behavior.
- Does cortical reinstatement **covary with hippocampal activity at retrieval?**

# HIPP Retrieval Activity: Correlates with Memory and Cortical Reinstatement

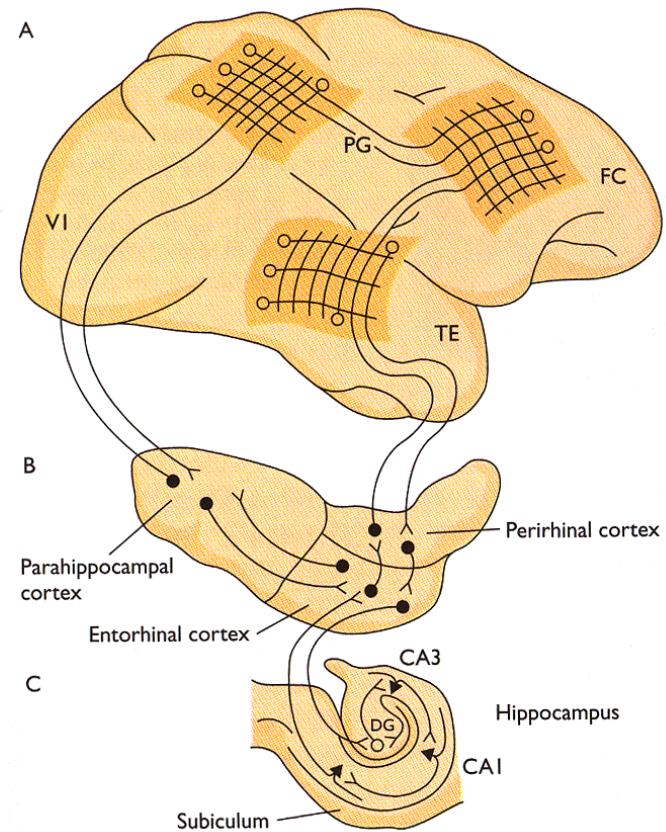
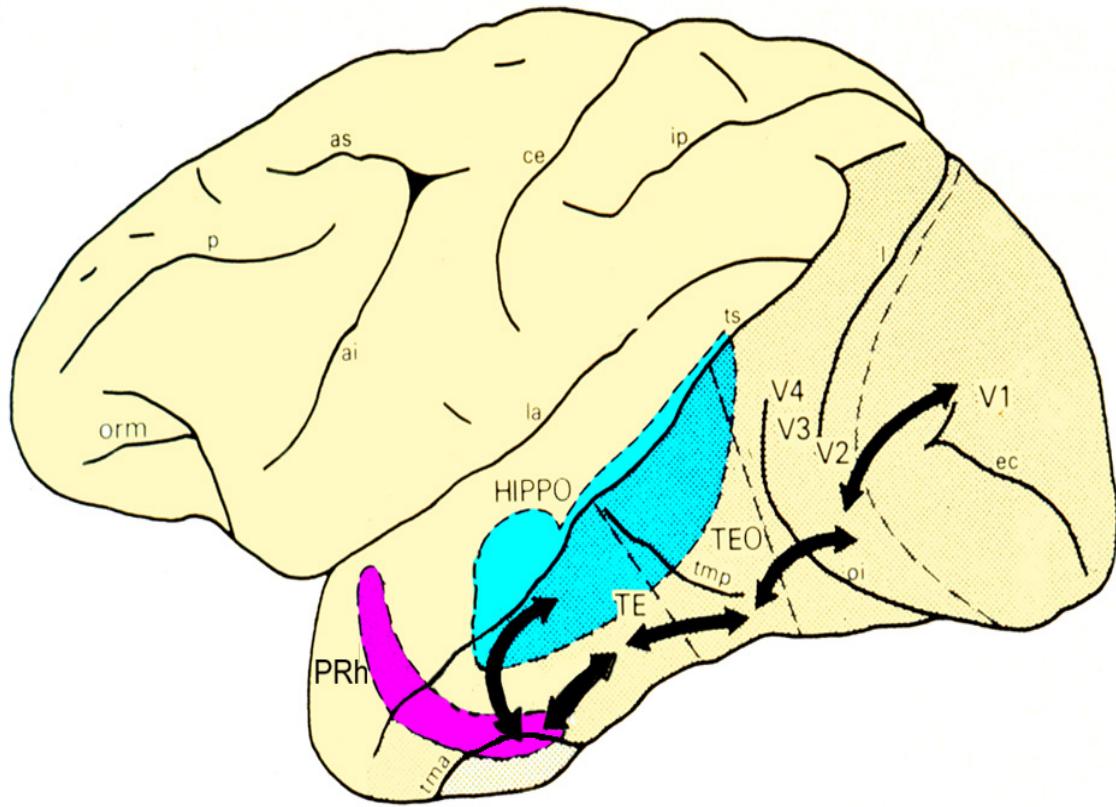


- As hippocampal activity at retrieval increases:
  - The probability of **correctly retrieving** associated thought increases
  - Retrieval **decisions are faster** (decreased response time; RT)
  - **Cortical reinstatement strength increases!**

# **Event Remembering: Cortical Reinstatement**

- Insights from **humans** (neuroimaging)
  - Remembering percepts
  - Remembering thoughts
- Insights from **monkeys** (direct recordings)
  - The role of the MTL in associative memory & reinstatement

# MTL Anatomy in Monkey Brain

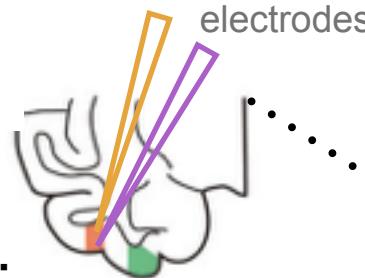


# Role of MTL in Associative Memory

Recorded regions

Area TE

Perirhinal



Hypothesized pre-learning activity:

TE neuron A

“optimal cue”

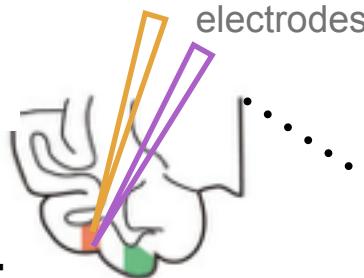


# Role of MTL in Associative Memory

Recorded regions

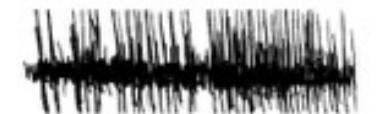
Area TE

Perirhinal



Hypothesized pre-learning activity:

TE neuron B

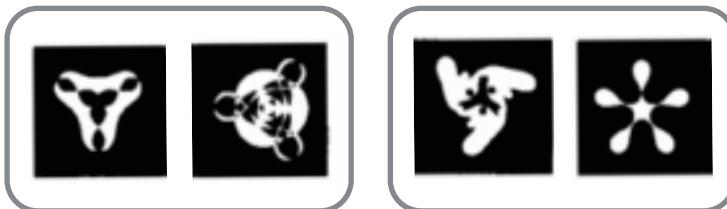


“optimal cue” →



# Role of MTL in Associative Memory

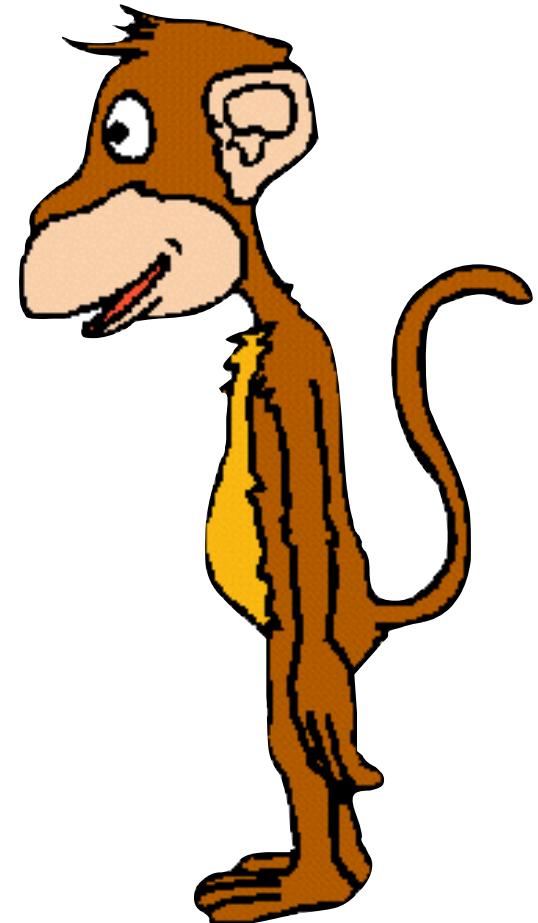
Example pairs:



## Pair-Association Task

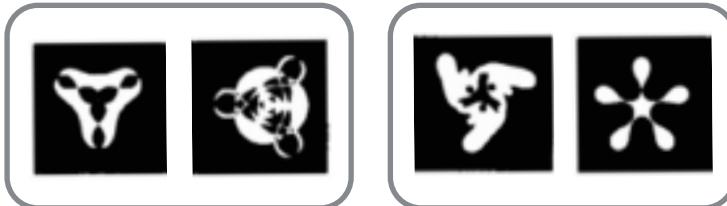


- **Create pairs** of “optimal cues” and “associates”; either can be the presented cue
- Monkeys learn to choose the other member of the pair associated with each cue picture

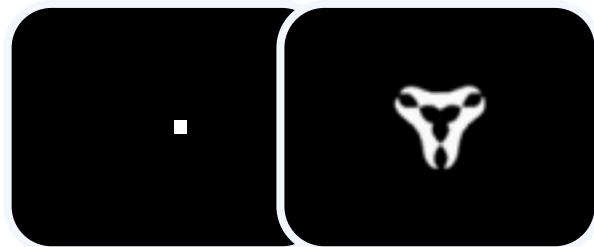


# Role of MTL in Associative Memory

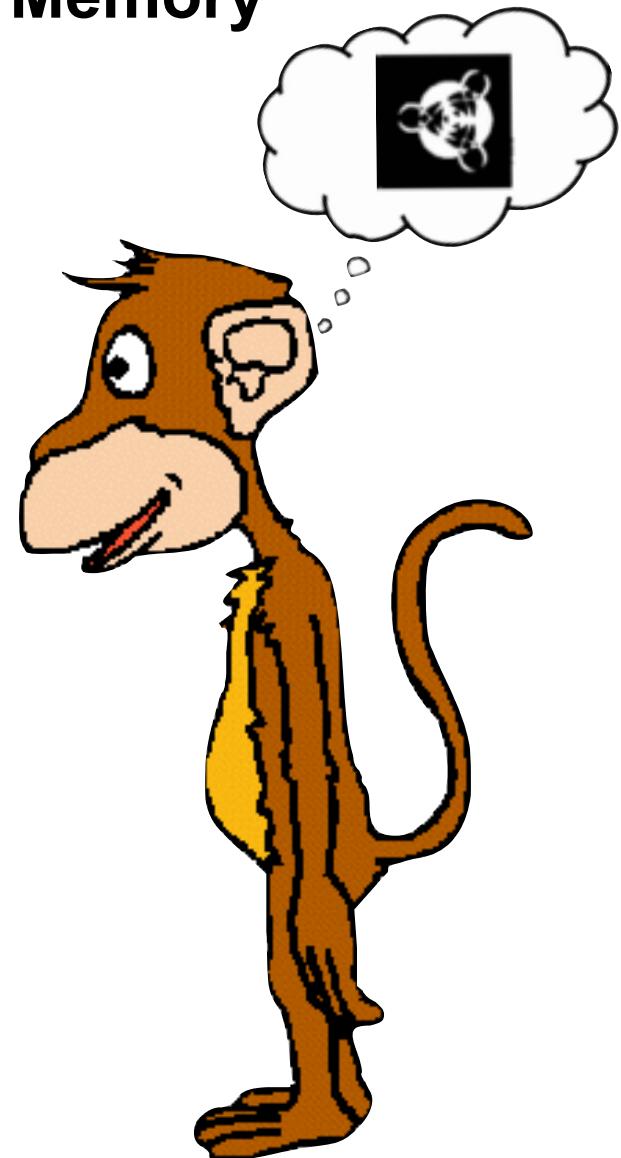
Example pairs:



## Pair-Association Task



- **Create pairs** of “optimal cues” and “associates”; either can be the presented cue
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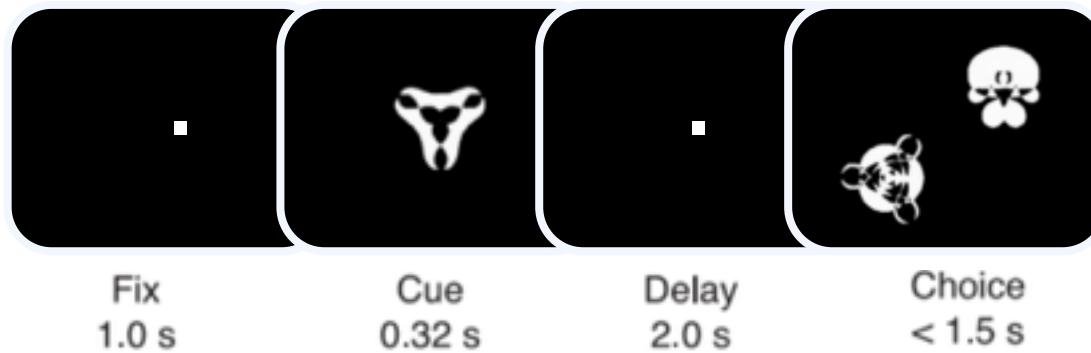


# Role of MTL in Associative Memory

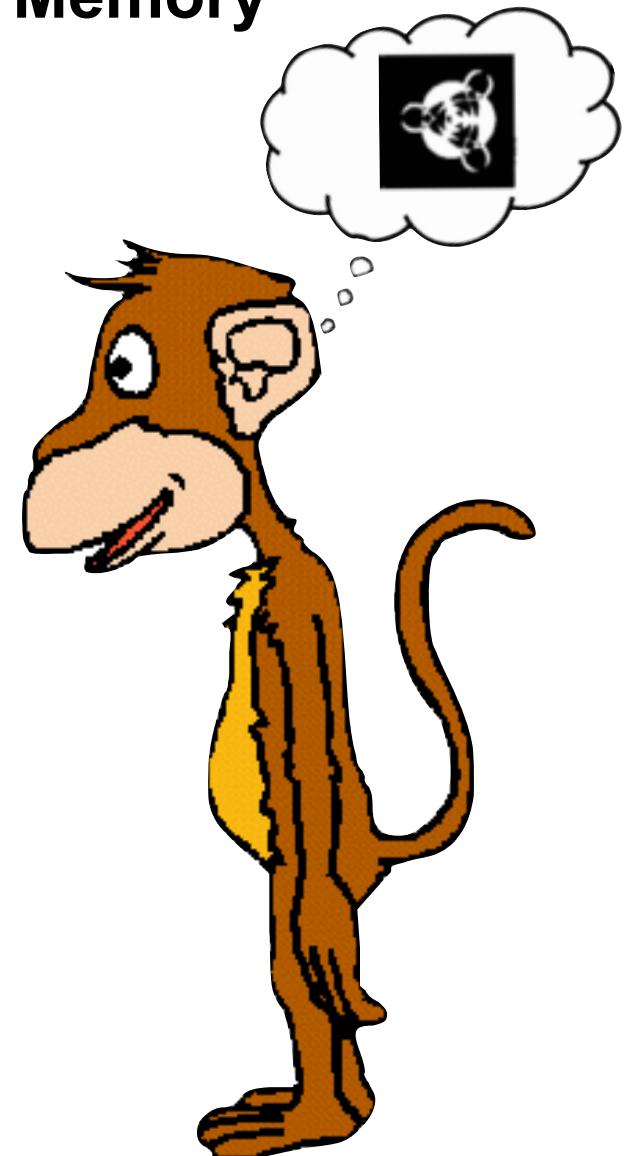
Example pairs:



## Pair-Association Task

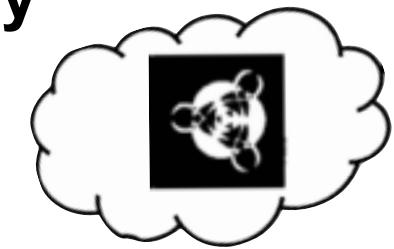
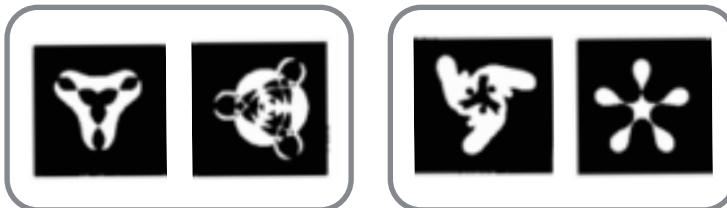


- **Create pairs** of “optimal cues” and “associates”; either can be the presented cue
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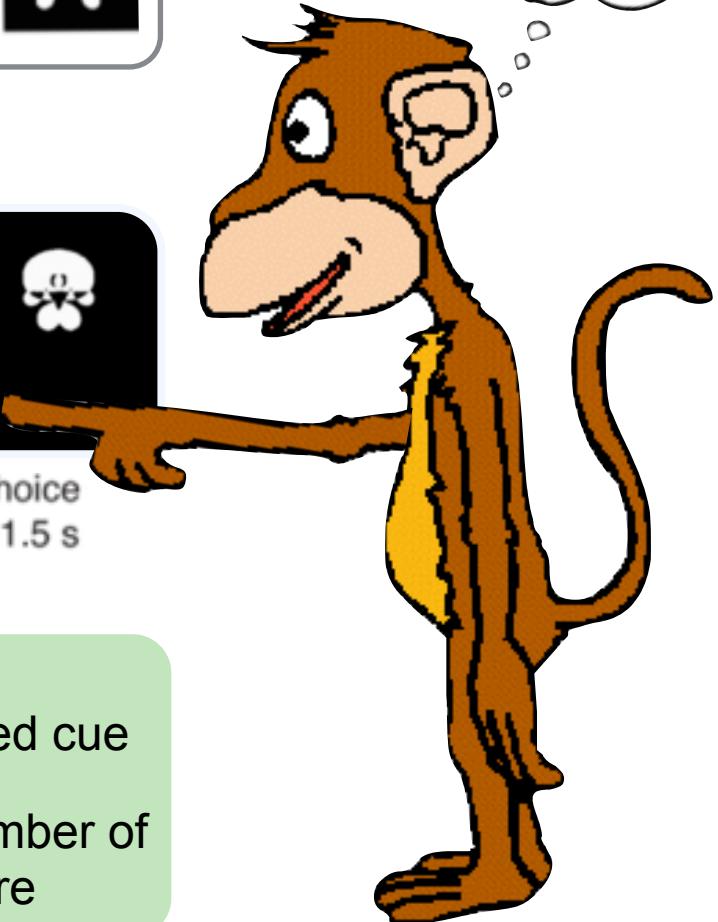
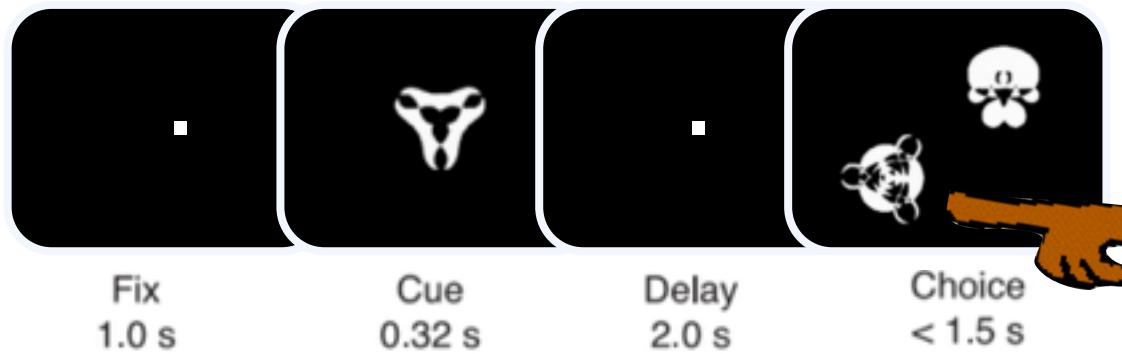


# Role of MTL in Associative Memory

Example pairs:

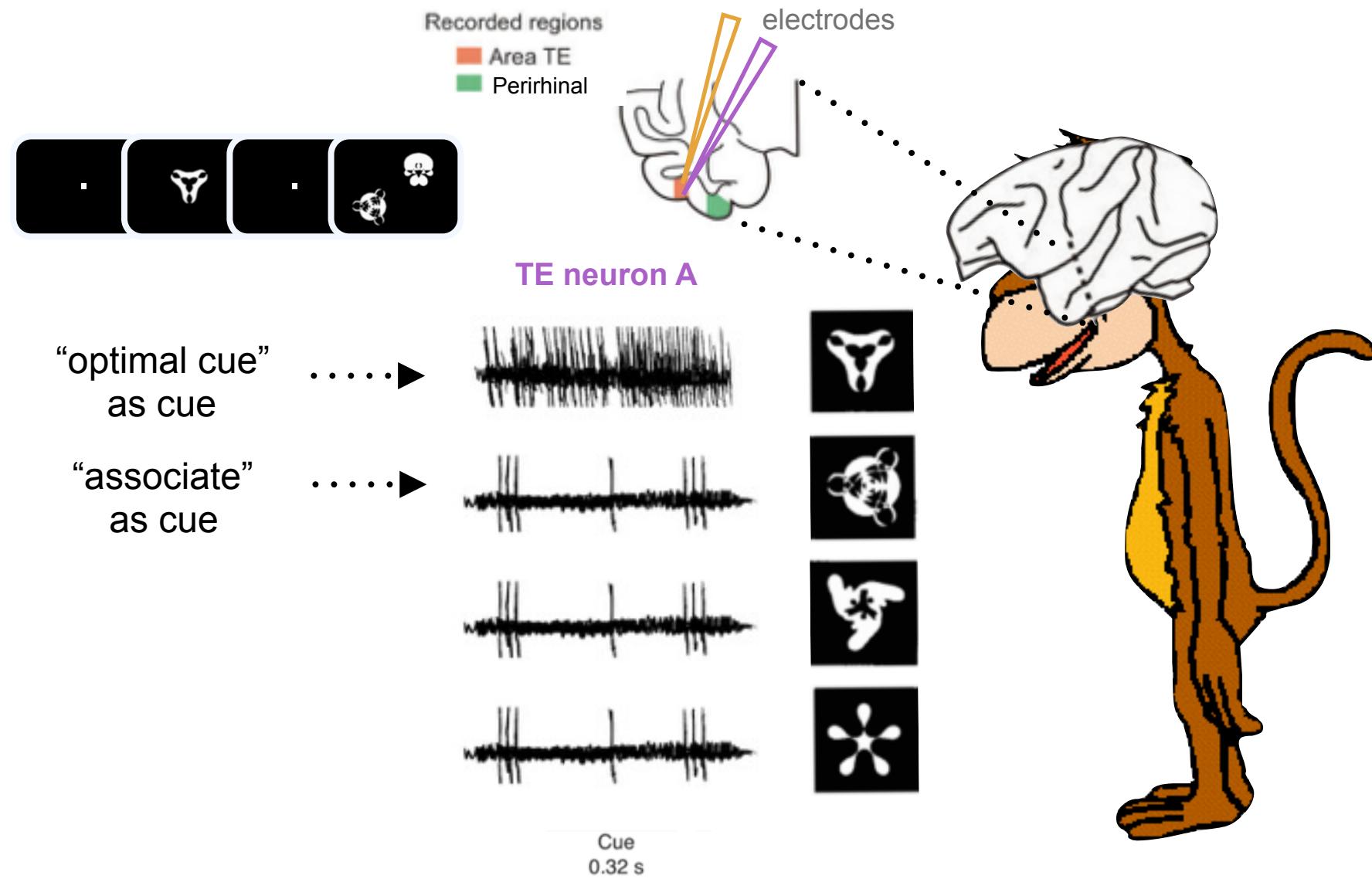


## Pair-Association Task

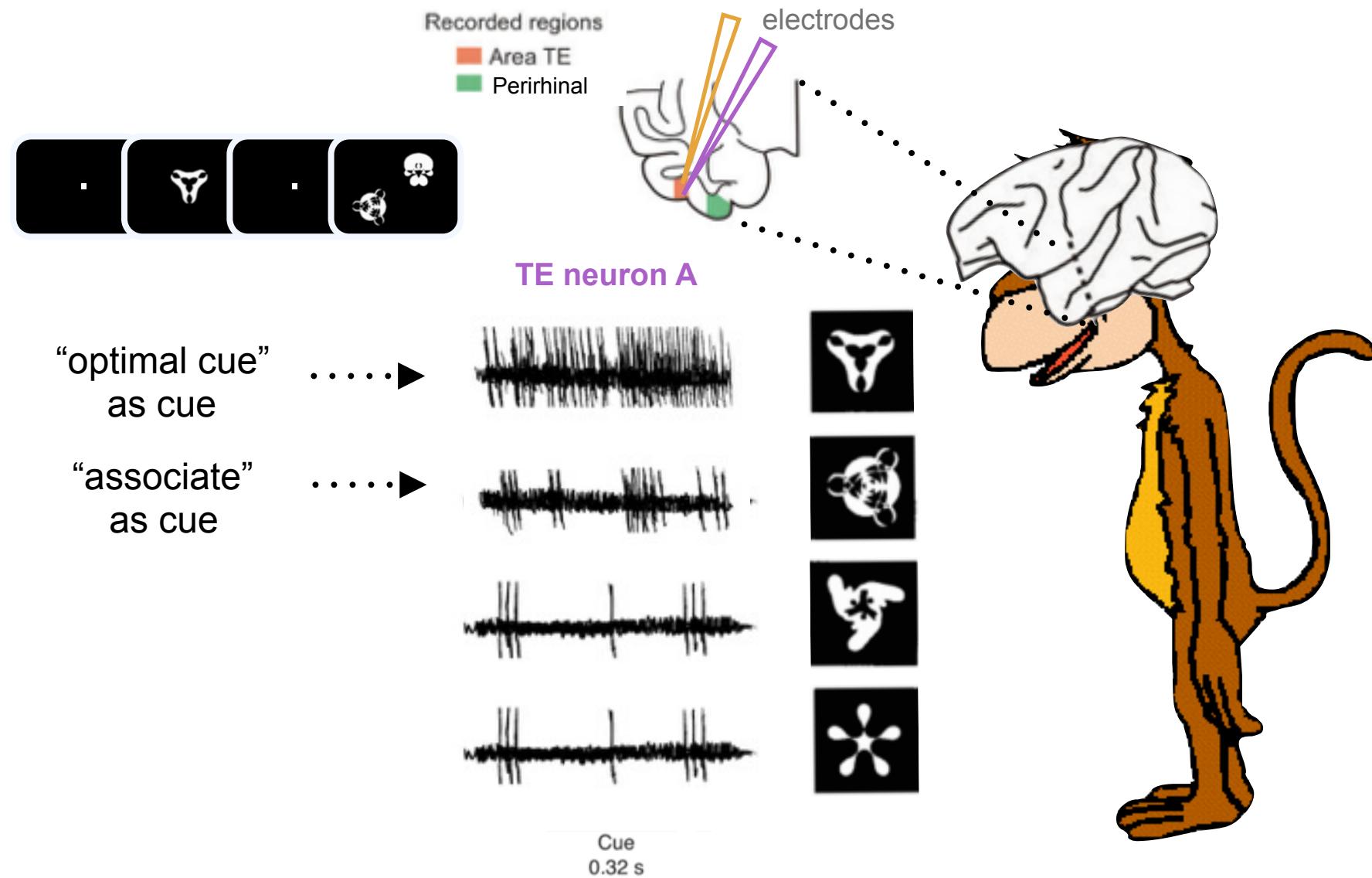


- **Create pairs** of “optimal cues” and “associates”; either can be the presented cue
- Monkeys learn to choose the other member of the pair associated with each cue picture

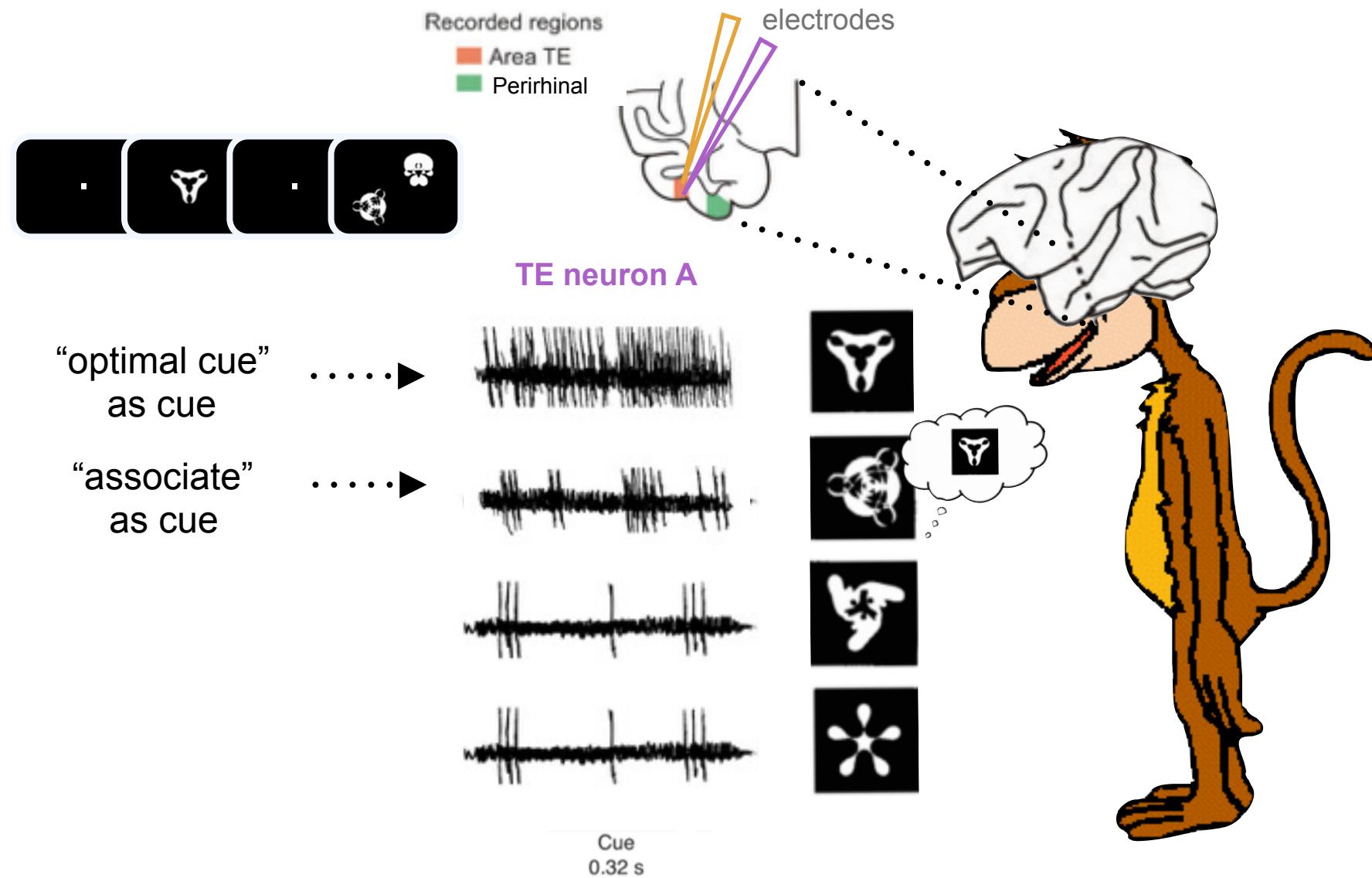
# Role of MTL in Associative Memory



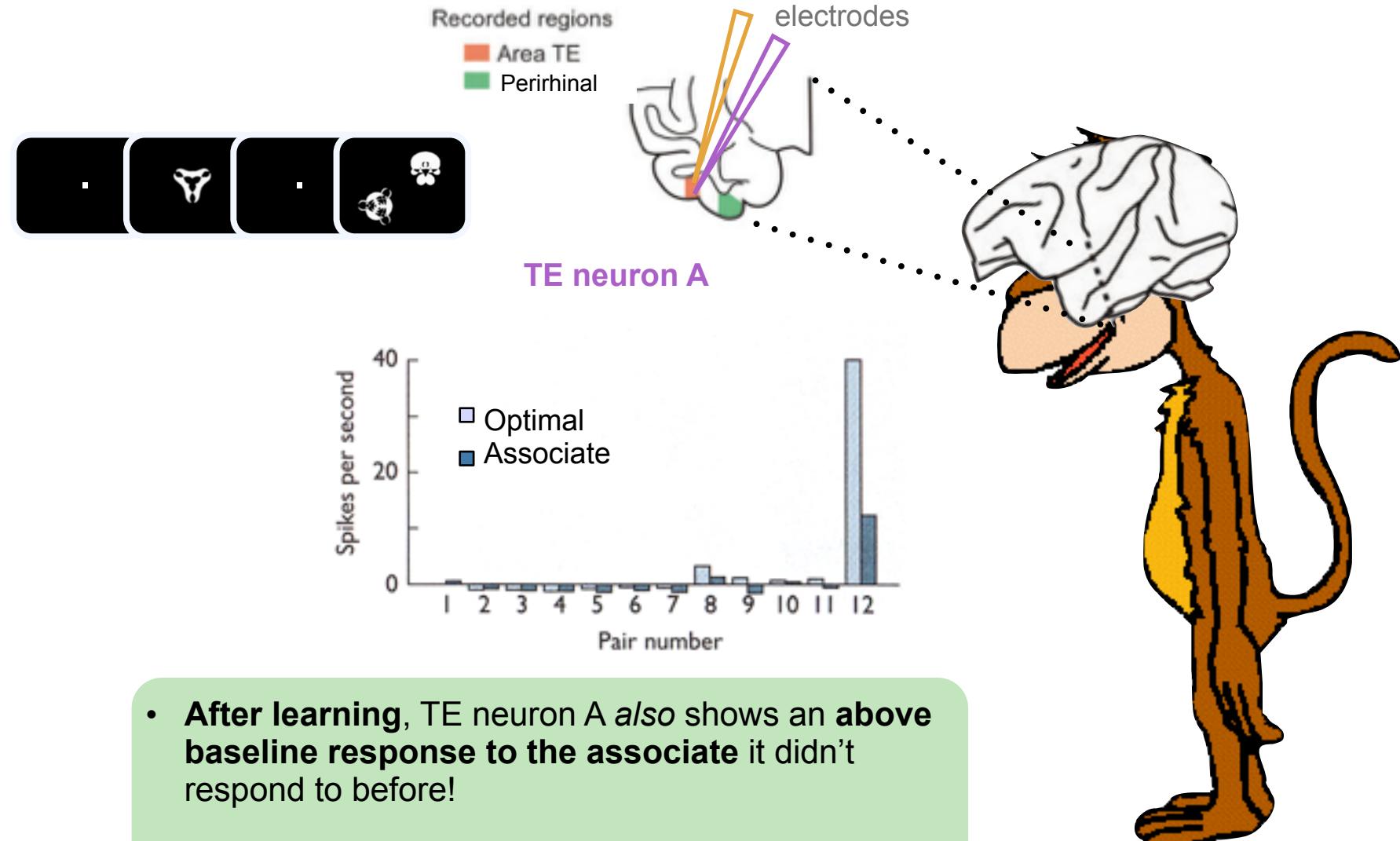
# Role of MTL in Associative Memory



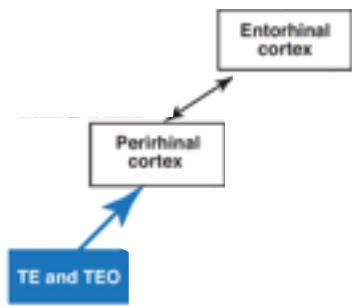
# Role of MTL in Associative Memory



# Role of MTL in Associative Memory



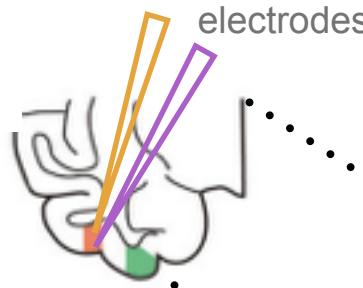
# Role of MTL in Associative Memory



Recorded regions

Area TE

Perirhinal



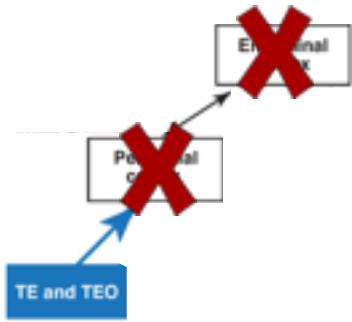
TE neuron A

“optimal cue”  
as cue

“associate”  
as cue



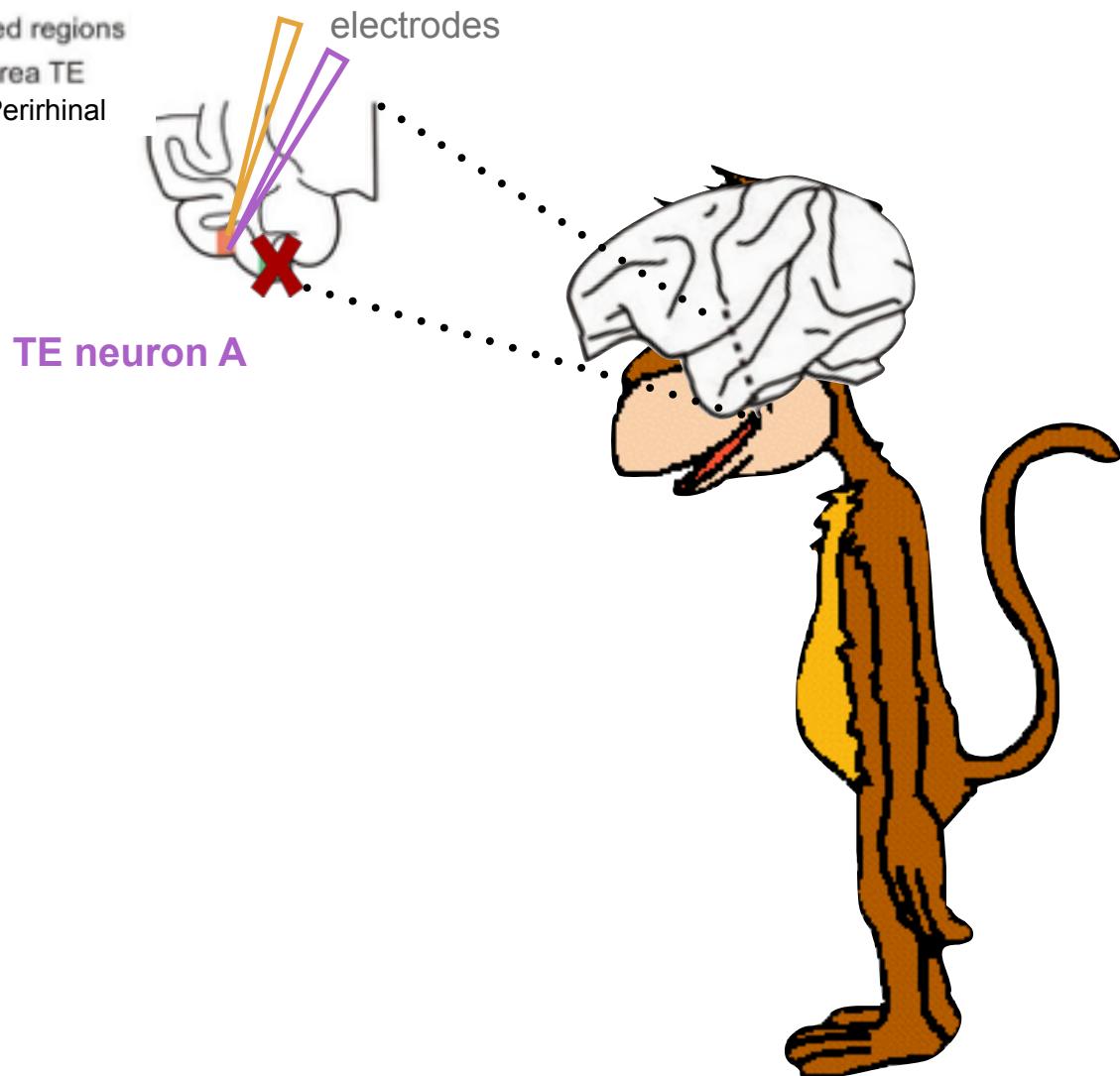
# Role of MTL in Associative Memory



Recorded regions

Area TE

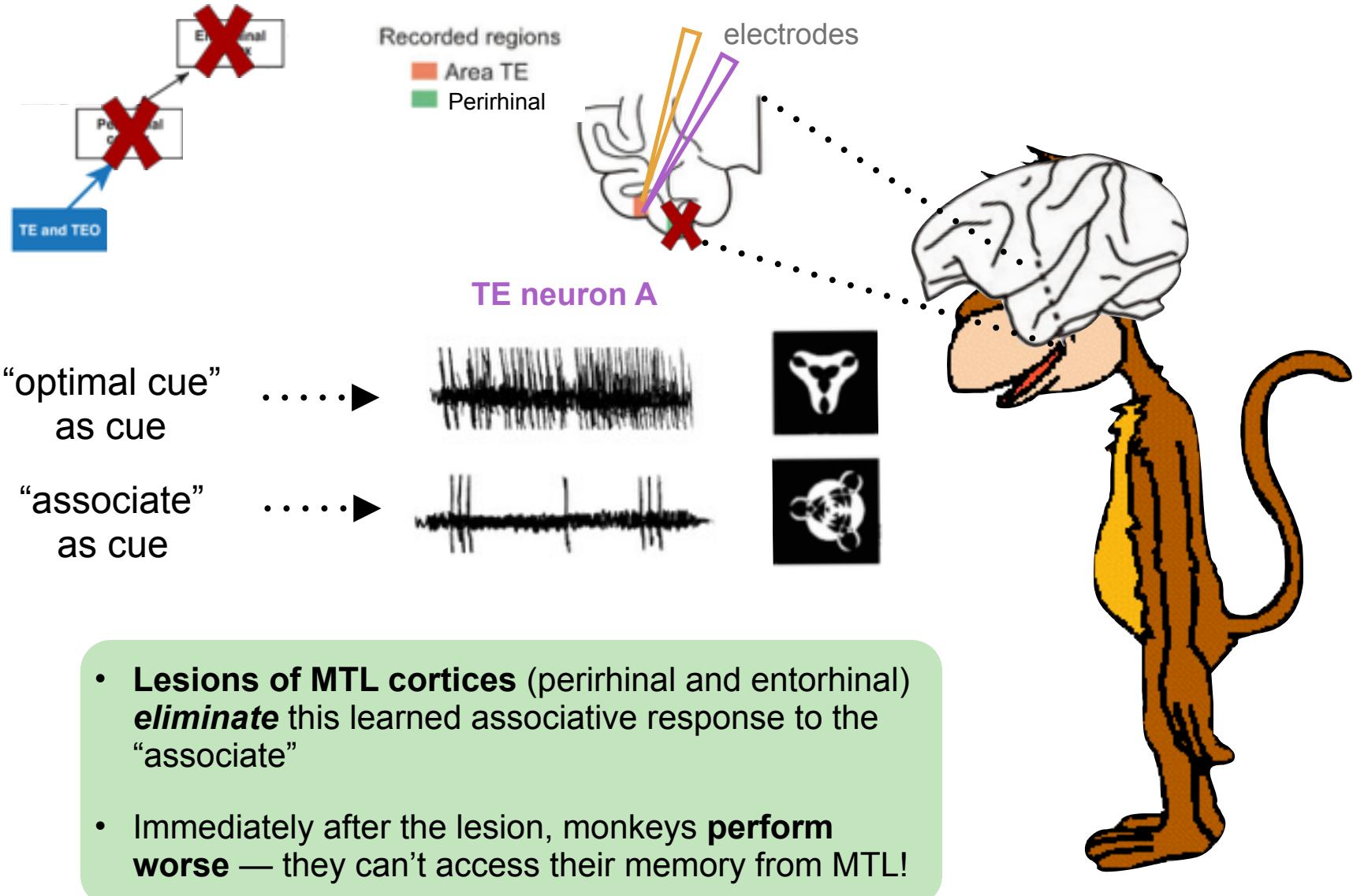
Perirhinal



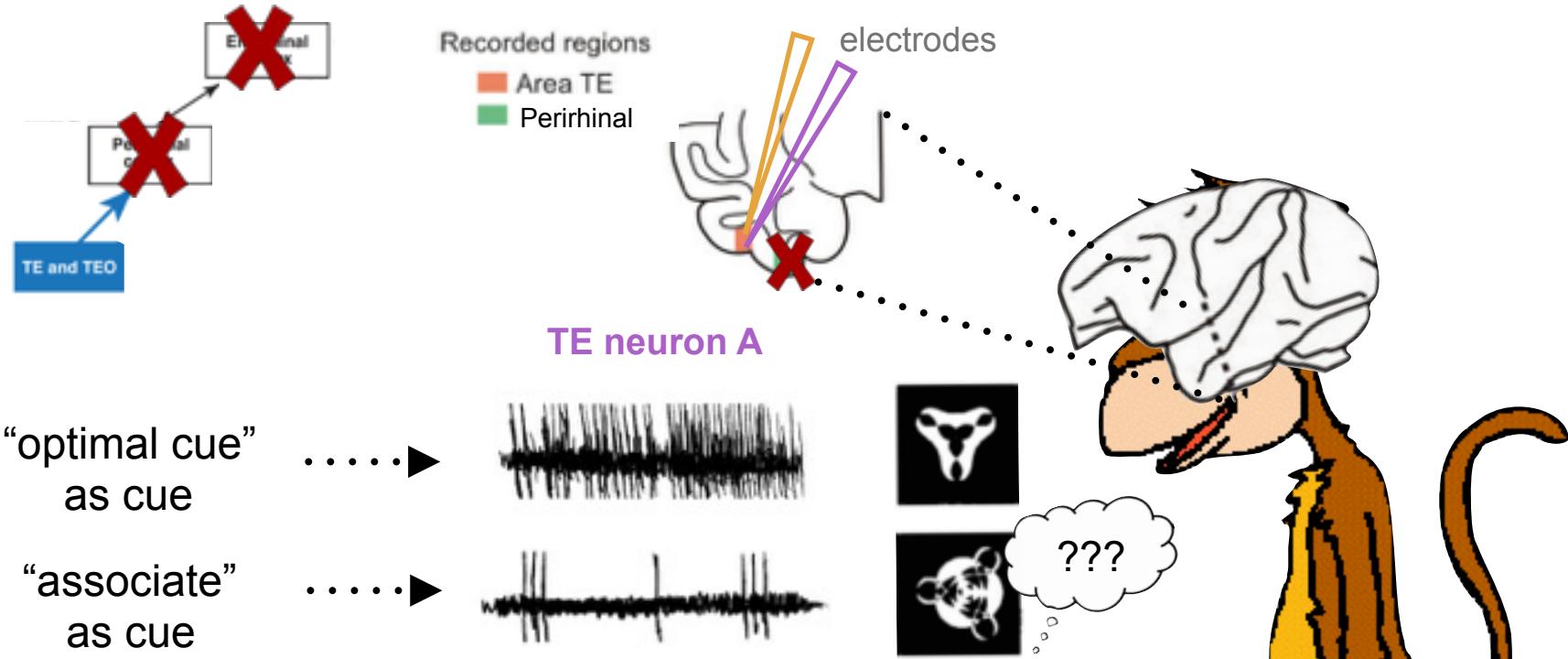
“optimal cue”  
as cue

“associate”  
as cue

# Role of MTL in Associative Memory

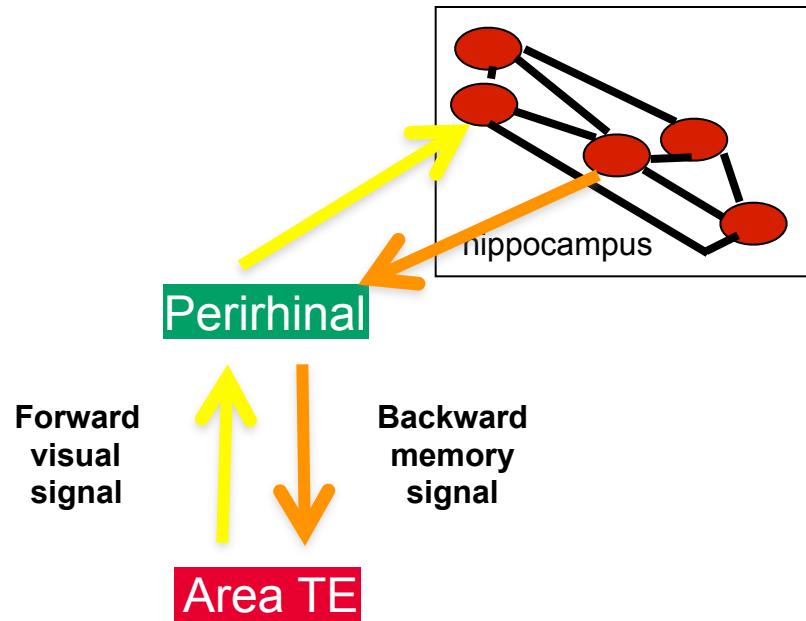


# Role of MTL in Associative Memory



- **Lesions of MTL cortices** (perirhinal and entorhinal) **eliminate** this learned associative response to the “associate”
- Immediately after the lesion, monkeys **perform worse** — they can't access their memory from MTL!

# Role of MTL in Cortical Reinstatement

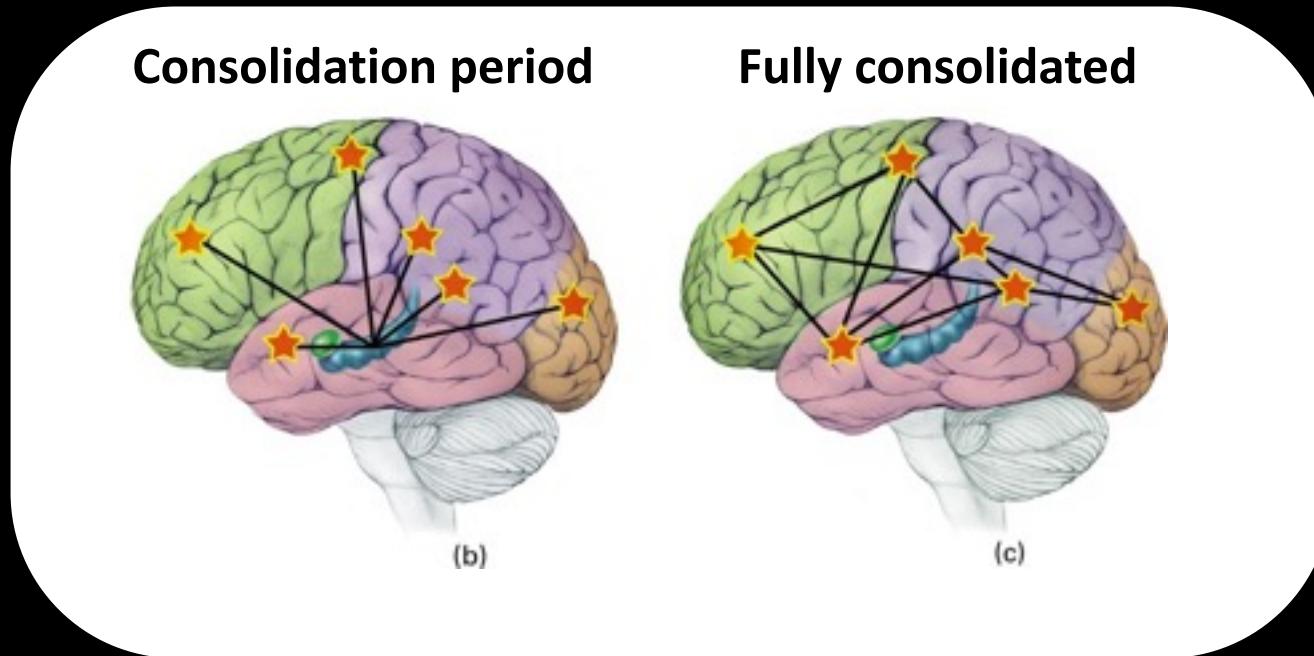


# Outline

---

- Principles of Episodic Retrieval
  - Pattern Completion and Reinstatement
  - Consolidation, redux
  - Cue-dependent Nature of Retrieval
- Recognition Memory

# Role of Reinforcement in Consolidation



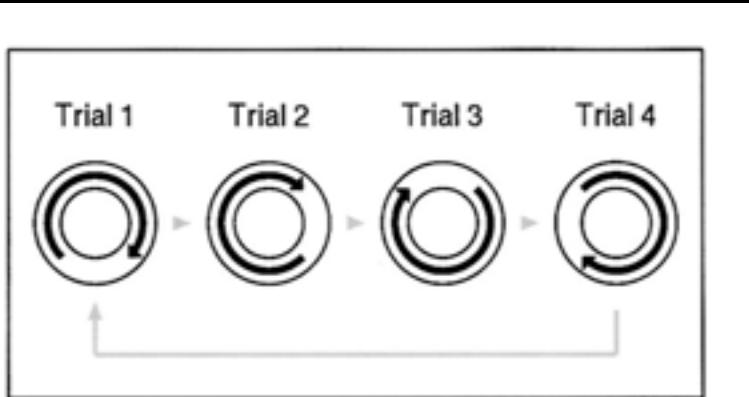
MTL damage impairs recent memories still undergoing consolidation, but memories fully consolidated (in the cortex) remain intact.

**Consolidation:** Occurs via hippocampal-dependent cortical reinstatement during **awake-state remembering** and during **sleep-state replay**.

# Sleep-State Hippocampal Replay

## Awake Behavior

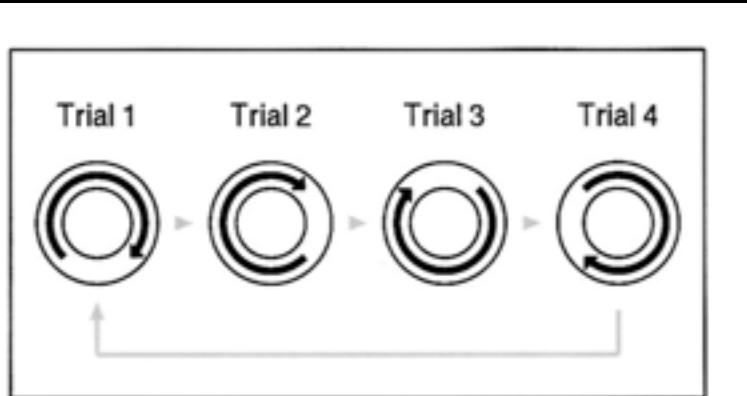
A



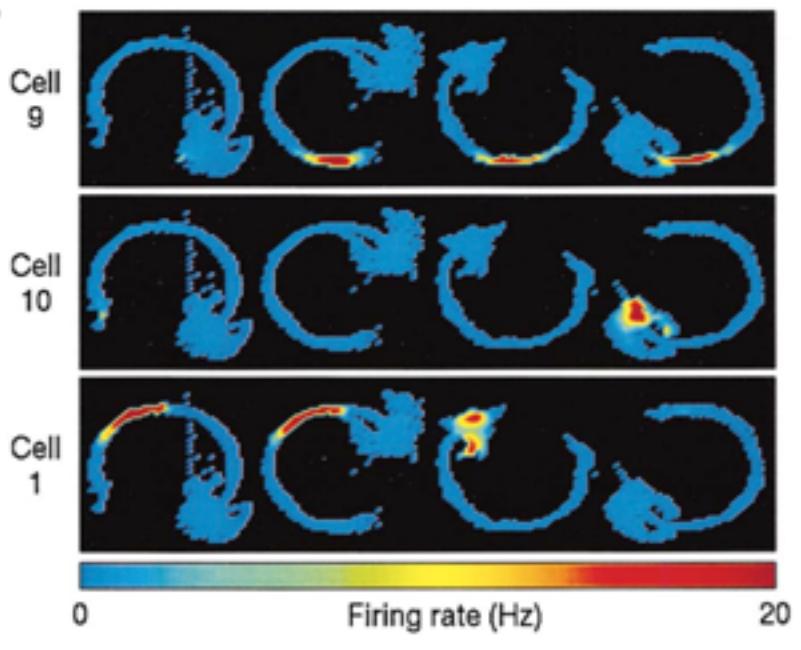
# Sleep-State Hippocampal Replay

## Awake Behavior

A



B

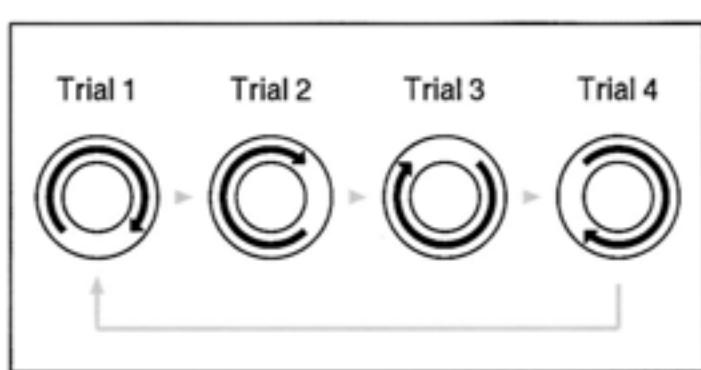


Awake Hippocampal  
“Place Cell” Activity

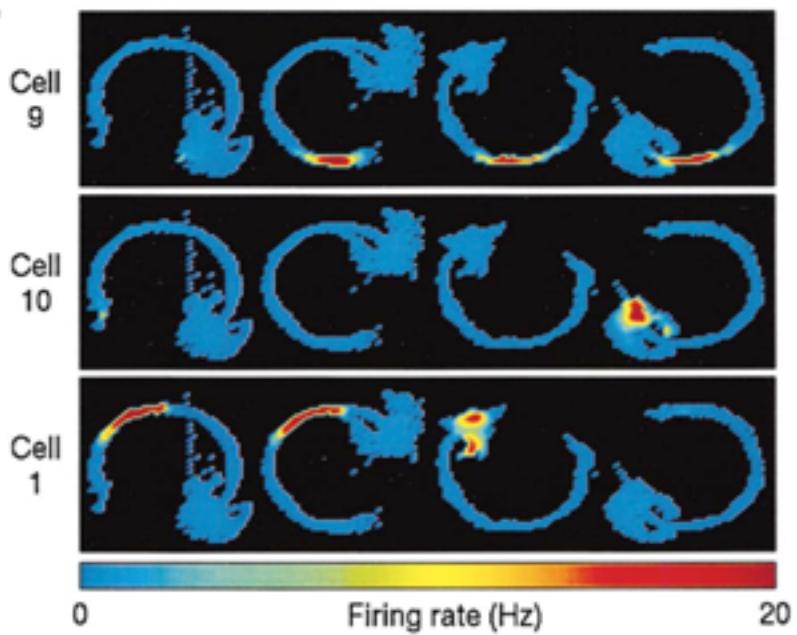
# Sleep-State Hippocampal Replay

## Awake Behavior

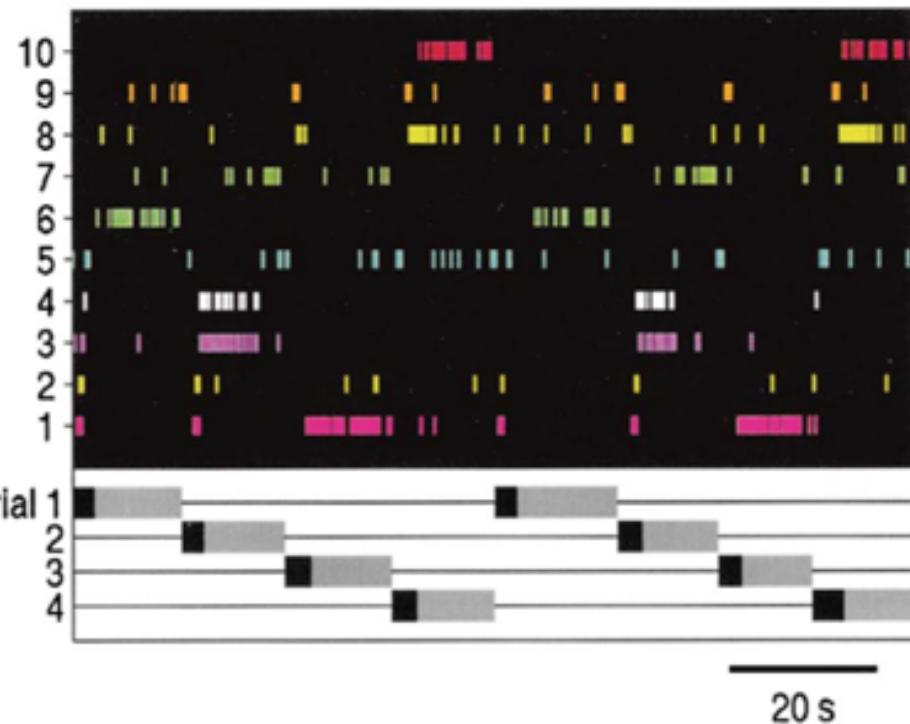
A



B

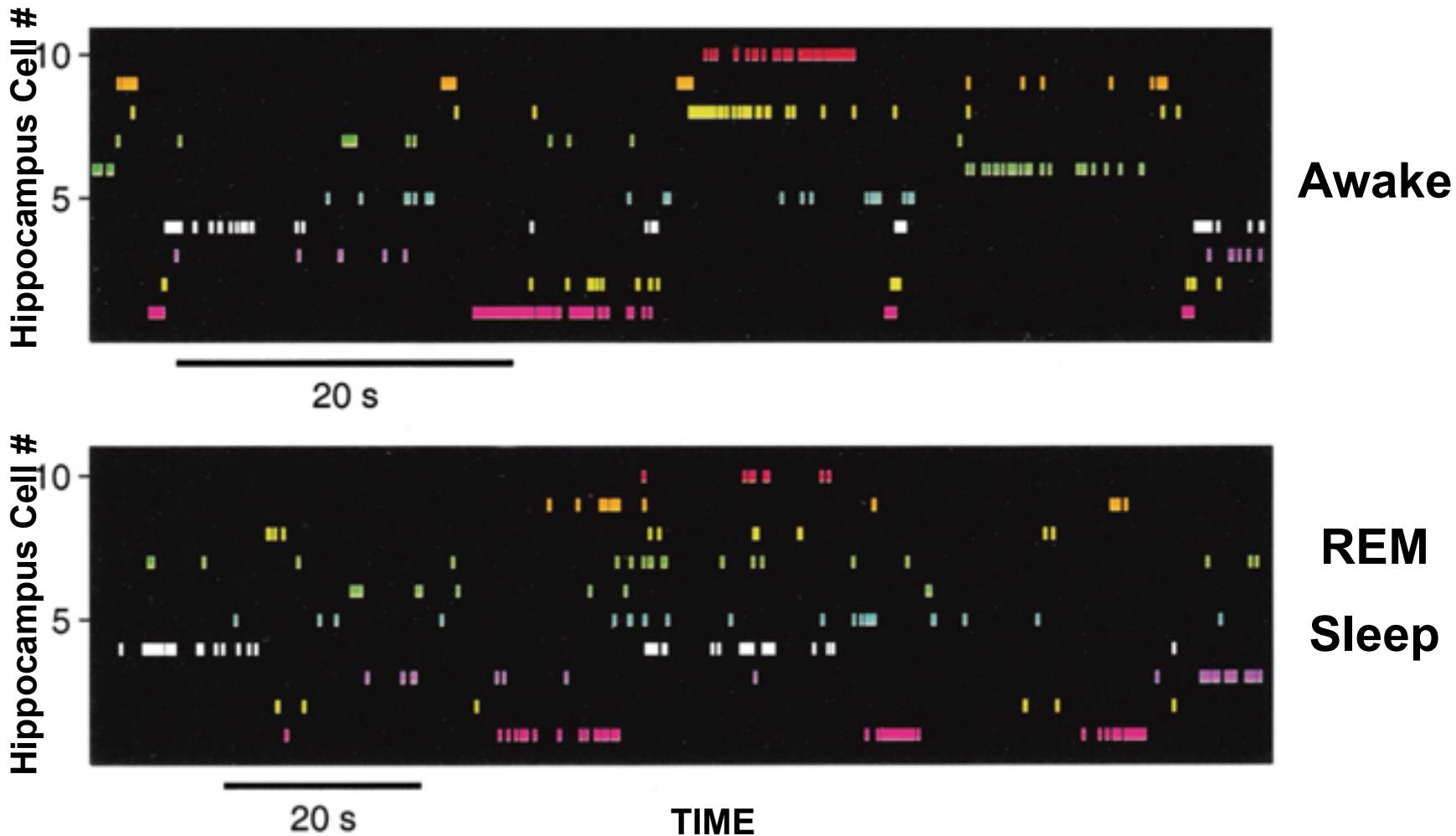


Hippocampus Place Cell #



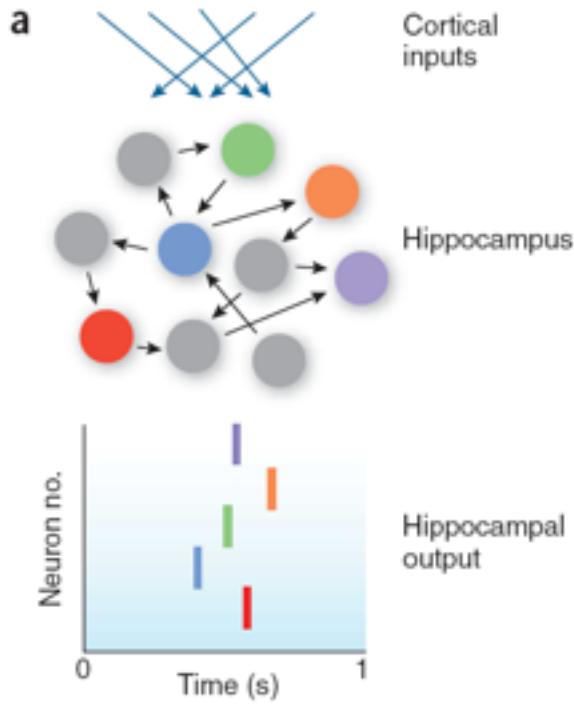
Awake Hippocampal  
“Place Cell” Activity

# Sleep-State Hippocampal Replay



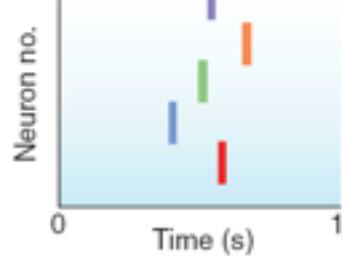
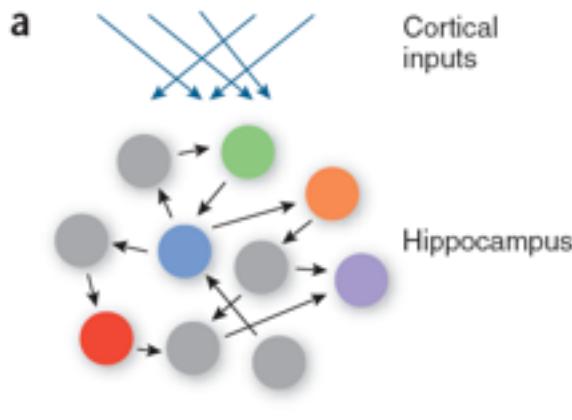
During REM sleep, hippocampal firing patterns replay the firing patterns that were present during the animal's day.

# Sleep-State Replay: MTL-Cortex Interactions

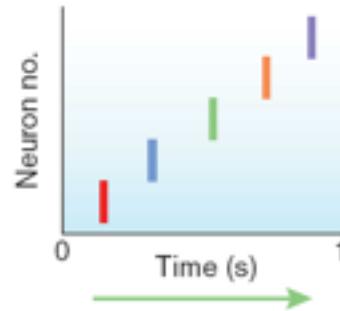
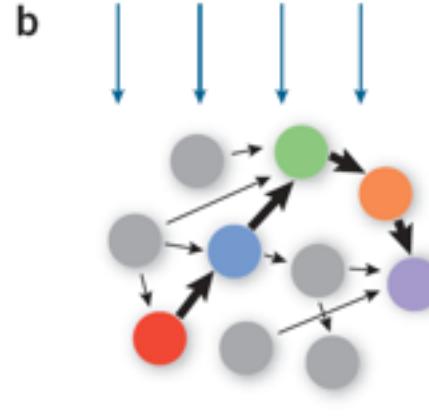


Sleep

# Sleep-State Replay: MTL-Cortex Interactions

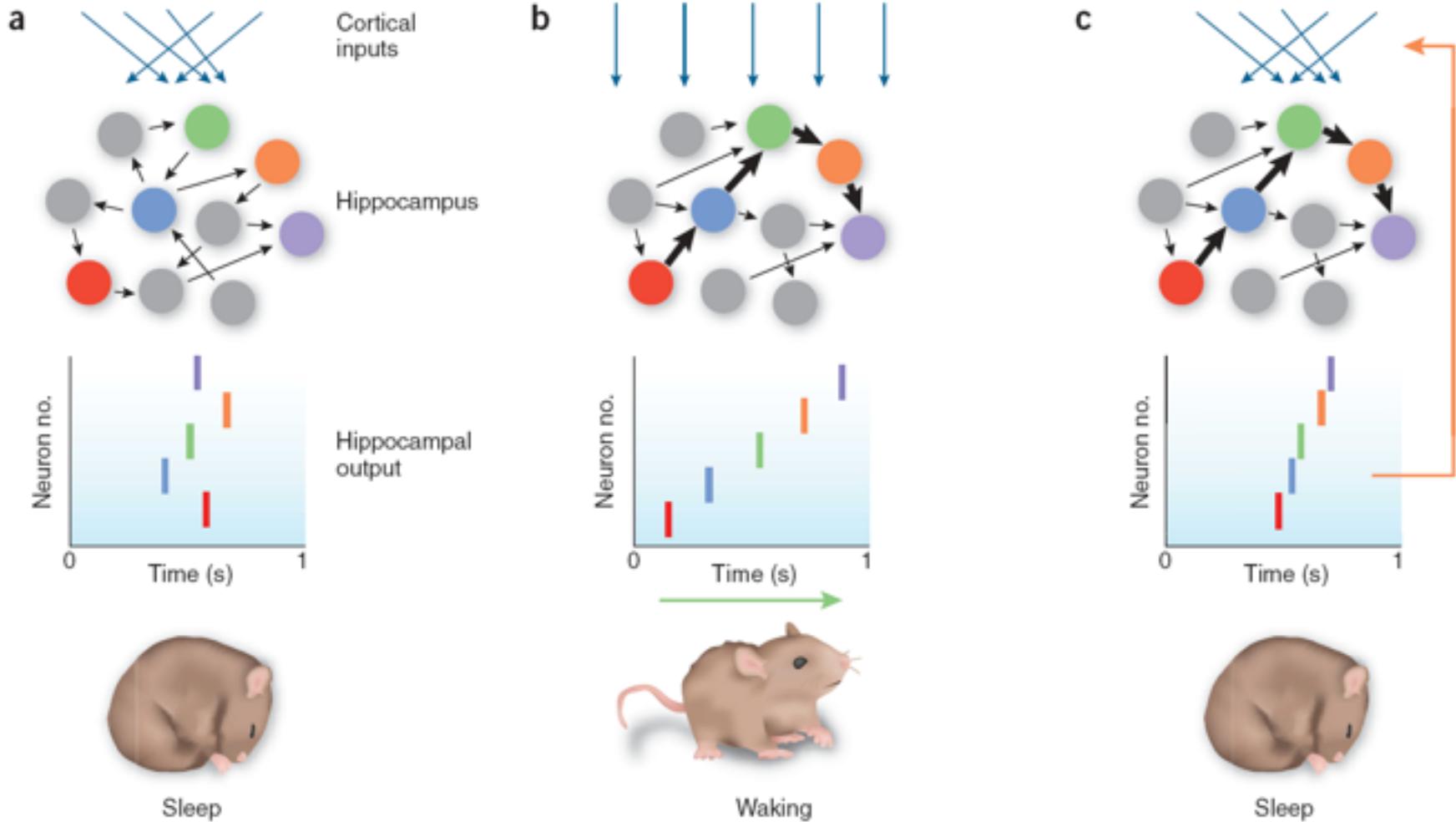


Sleep



Waking

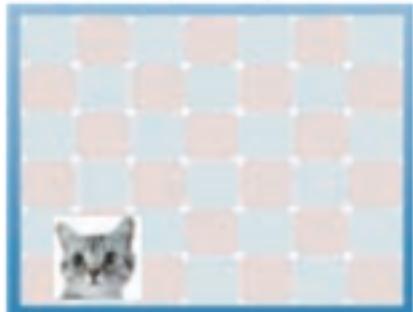
# Sleep-State Replay: MTL-Cortex Interactions



# Sleep-State Cueing of Specific Memories

## A Learning – 50 object locations

Subsequently cued



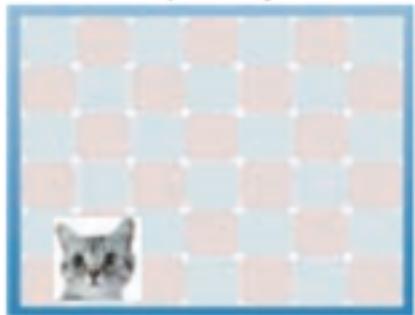
Subsequently uncued



# Sleep-State Cueing of Specific Memories

**A** Learning – 50 object locations

Subsequently cued

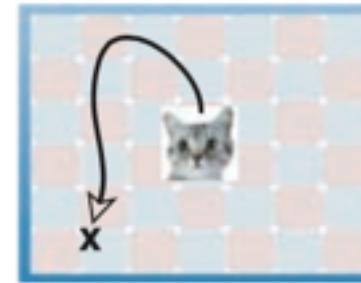


Subsequently uncued

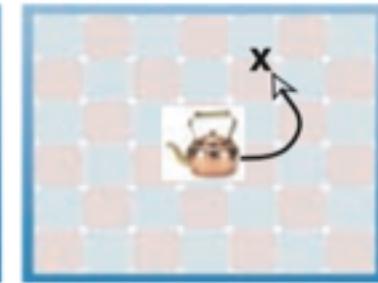


**C** Test – 50 object locations

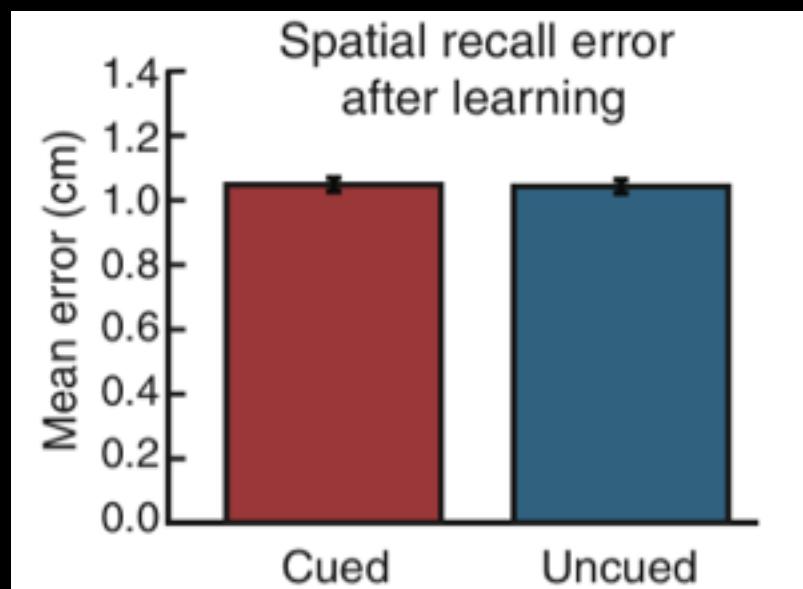
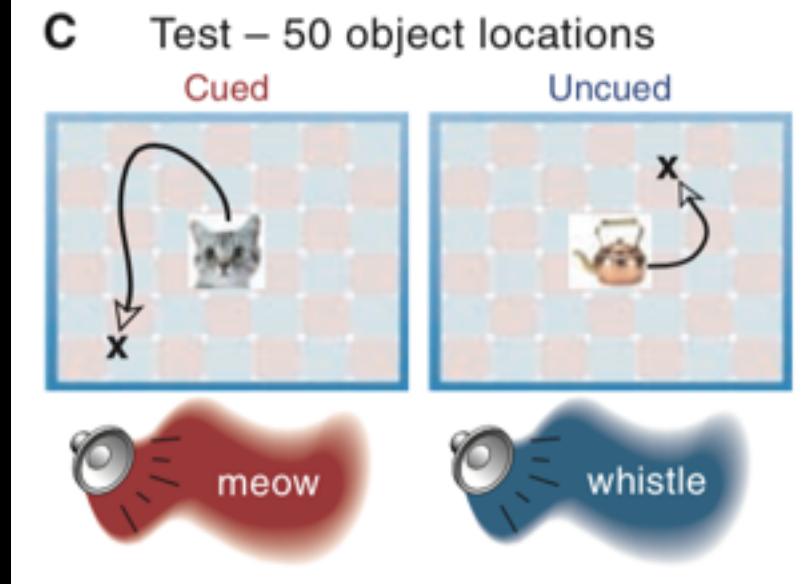
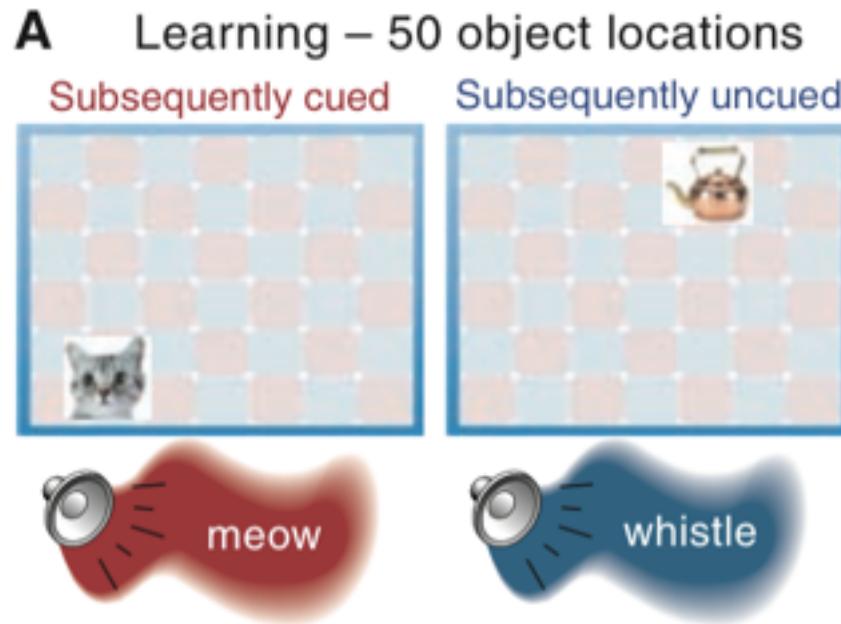
Cued



Uncued

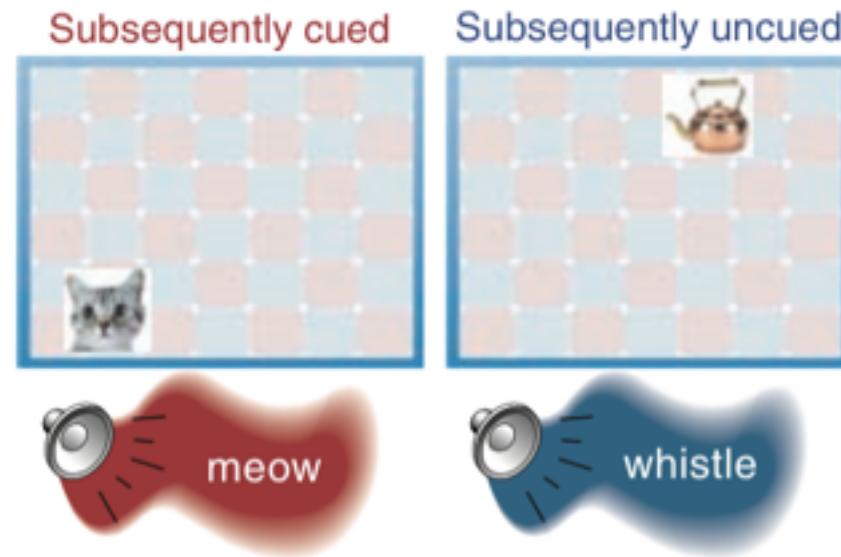


# Sleep-State Cueing of Specific Memories

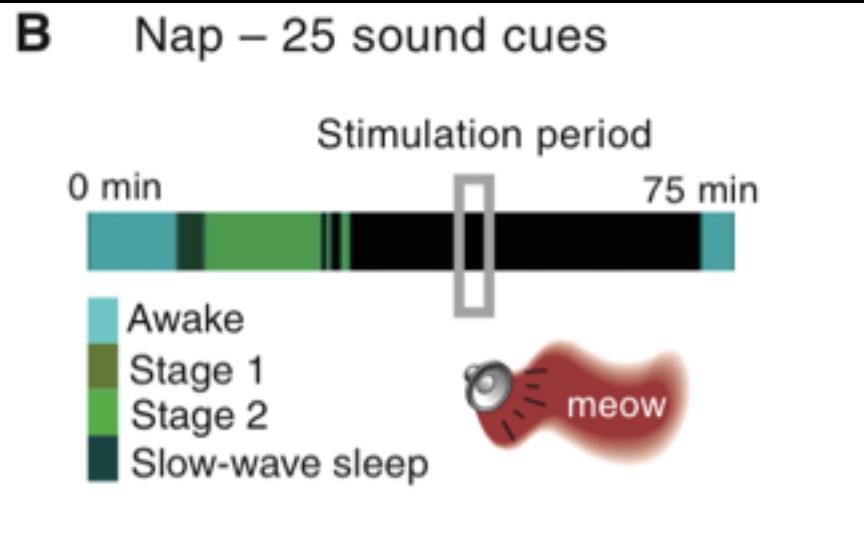


# Cueing the Replay of Specific Memories

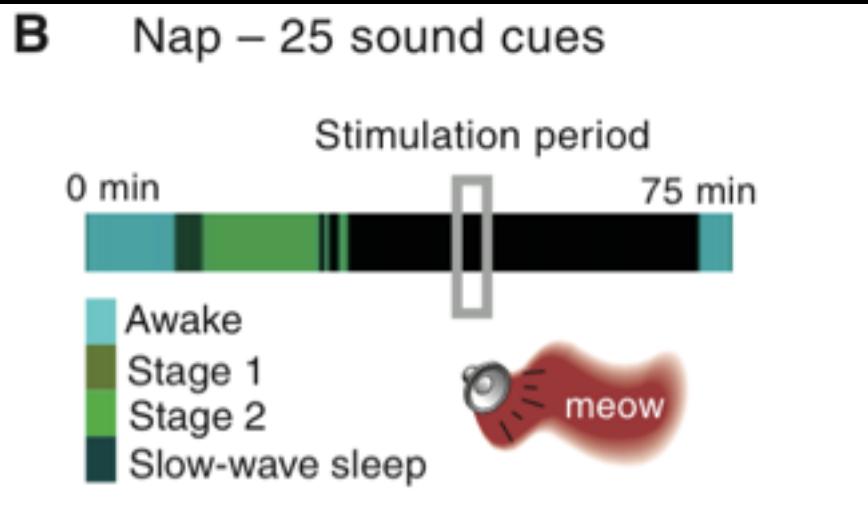
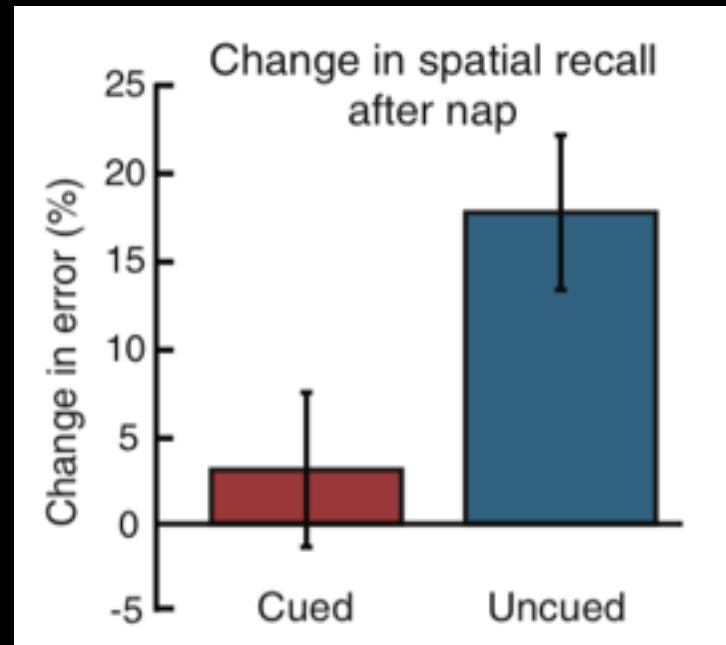
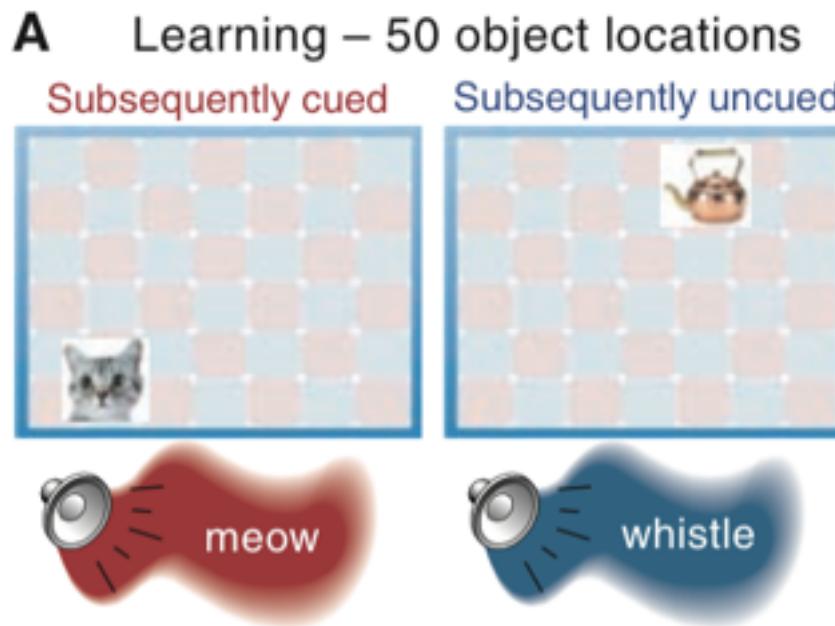
## A Learning – 50 object locations



## B Nap – 25 sound cues



# Cueing the Replay of Specific Memories

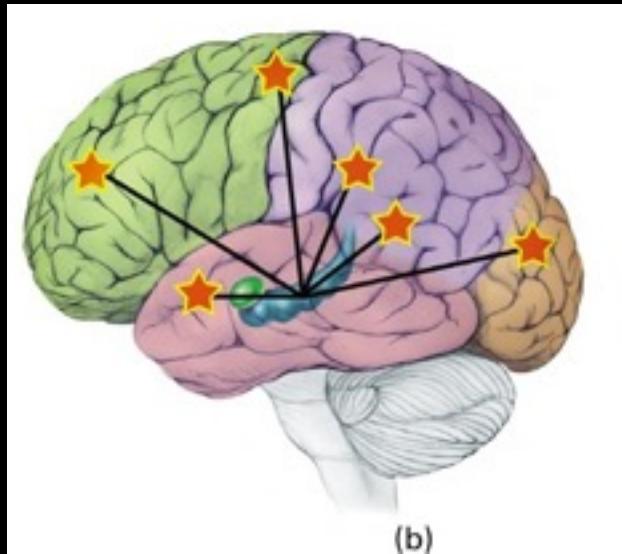


Replay of specific memories during sleep strengthens those memories, increasing the probability of remembering them in the future.

# Participation Prompt #2

- Try to remember some experience from this past weekend, bringing as many details to mind
- Do you think what you've remembered contains all of the event information that you had encoded into episodic memory during the experience?
- Do you think what you've remembered is a highly accurate memory of the event, with no distortions or errors?
- If the answer to either of the above is 'no', what are the implications for how the event memory is being consolidated in cortex?

# Are Episodic Memories Ever Consolidated? Multiple Trace Theory



- True episodic memories are **never independent** of the MTL
- Spared memories seen in temporally-graded retrograde amnesia are **no longer episodic** memories
  - Rather, are autobiographical **semantic** knowledge

# Outline

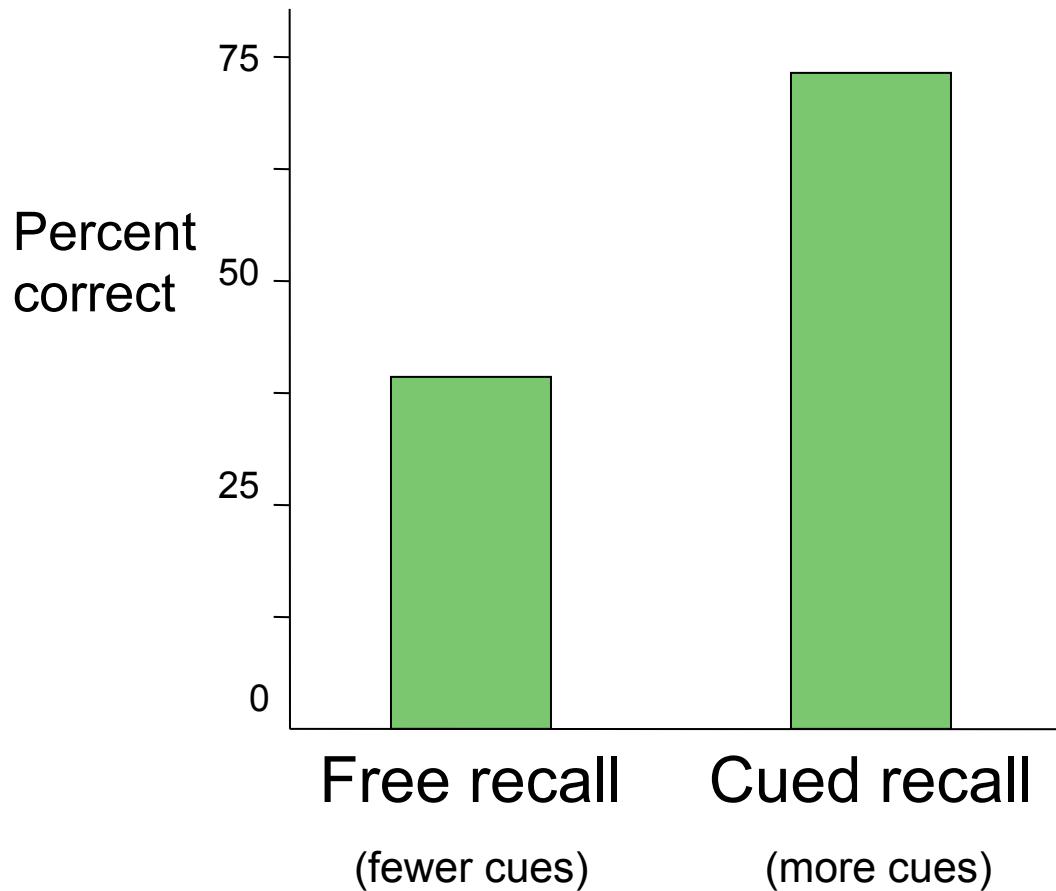
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- Principles of Episodic Retrieval
  - Pattern Completion and Reinstatement
  - Consolidation, redux
  - Cue-dependent Nature of Retrieval
- Recognition Memory

# How is Episodic Memory Tested?

- Subjects **study** a list of items
  - e.g., pictures, words
- Types of memory **tests**
  - **Free Recall**
    - *Please tell me all of the items that were on the study list*
  - **Cued Recall**
    - *Please tell me which word on the study list completes this stem:*  
mot \_\_\_\_\_
  - **Recognition**
    - *Did you see this item before: yes/no*
    - *Which of these items did you see before: forced-choice*

# Type of Test affects Assessment of Memory

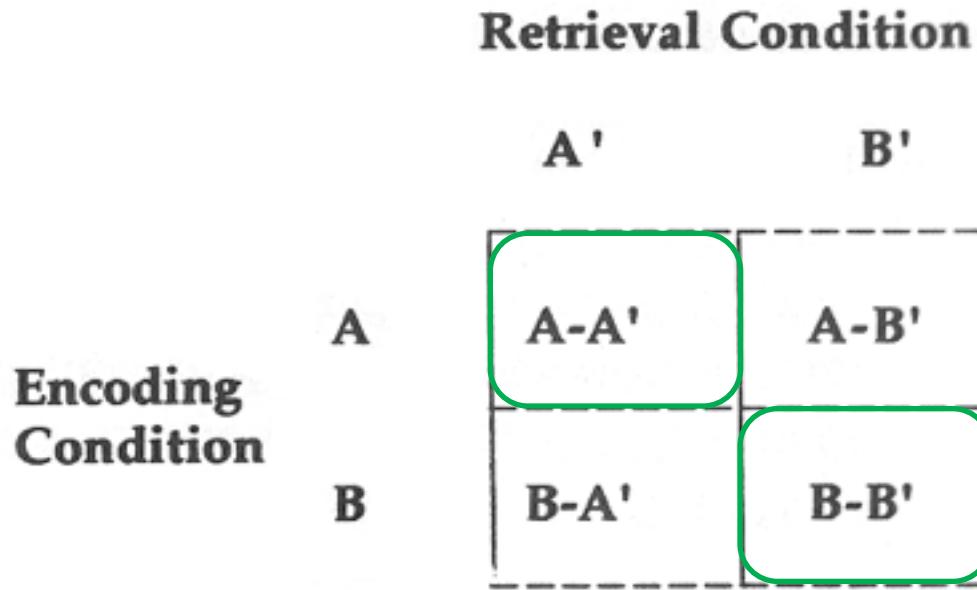


**Memory is cue dependent**

- **Greater cue support** (i.e., cued recall) results in **superior remembering**

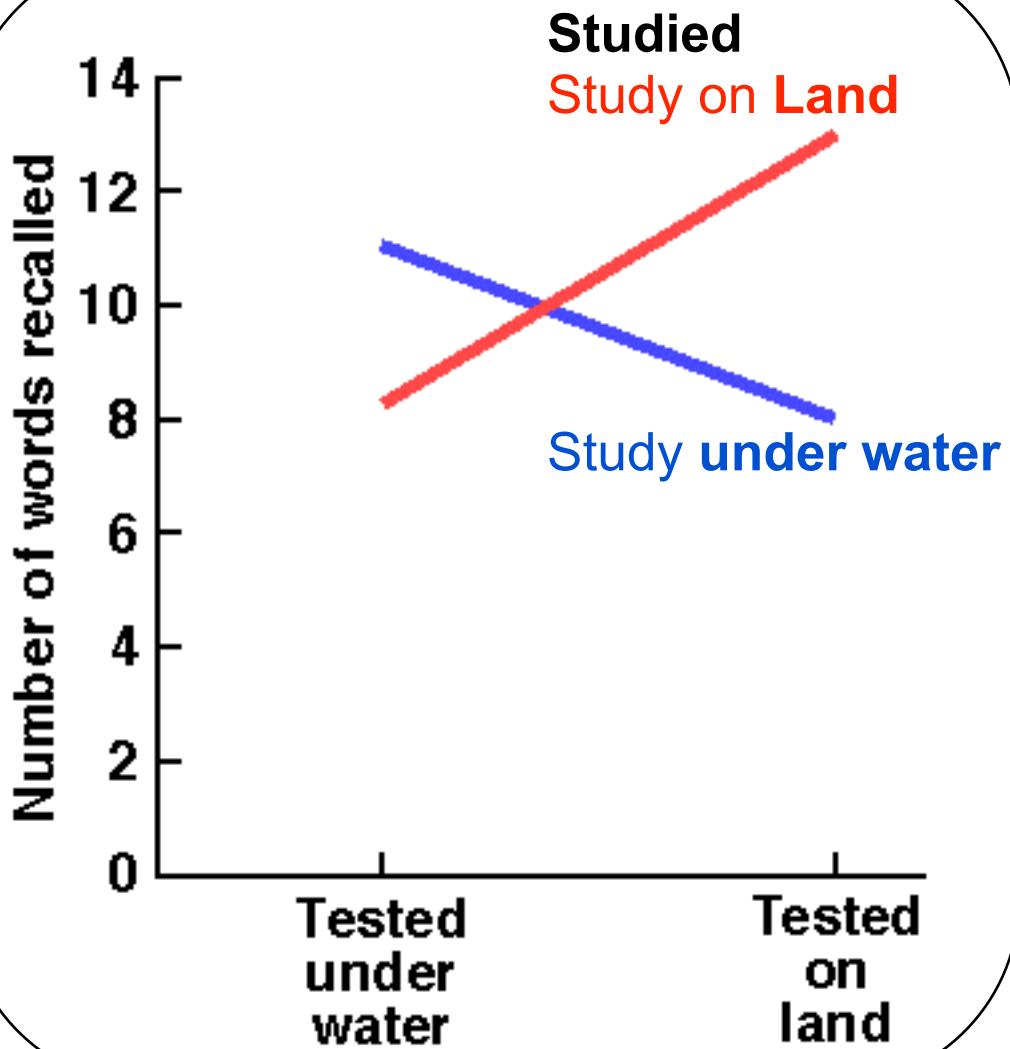
(Graf, Squire, & Mandler, 1984)

# Cue-Dependent Memory



- A is more similar to A' than B (or B'); B is more similar to B' than A (or A')
- **Memory better when tested in a similar condition to learning** ( $A-A'/B-B'$ ) relative to a dissimilar condition ( $A-B'/B-A'$ )

# Context-Dependent Memory



- External context contains stimuli that become associated with the learned material
- These contextual stimuli are useful cues for eliciting retrieval of these memories



(Godden & Baddeley, 1975)

# Context–Dependent Memory

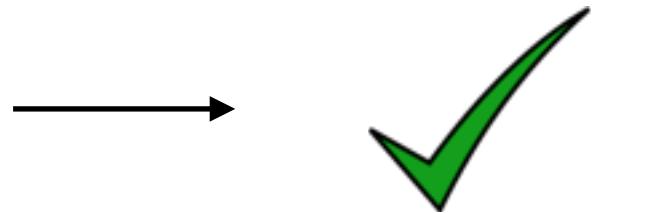
STUDY



TEST



PERFORMANCE



# Context–Dependent Memory

STUDY



TEST



PERFORMANCE



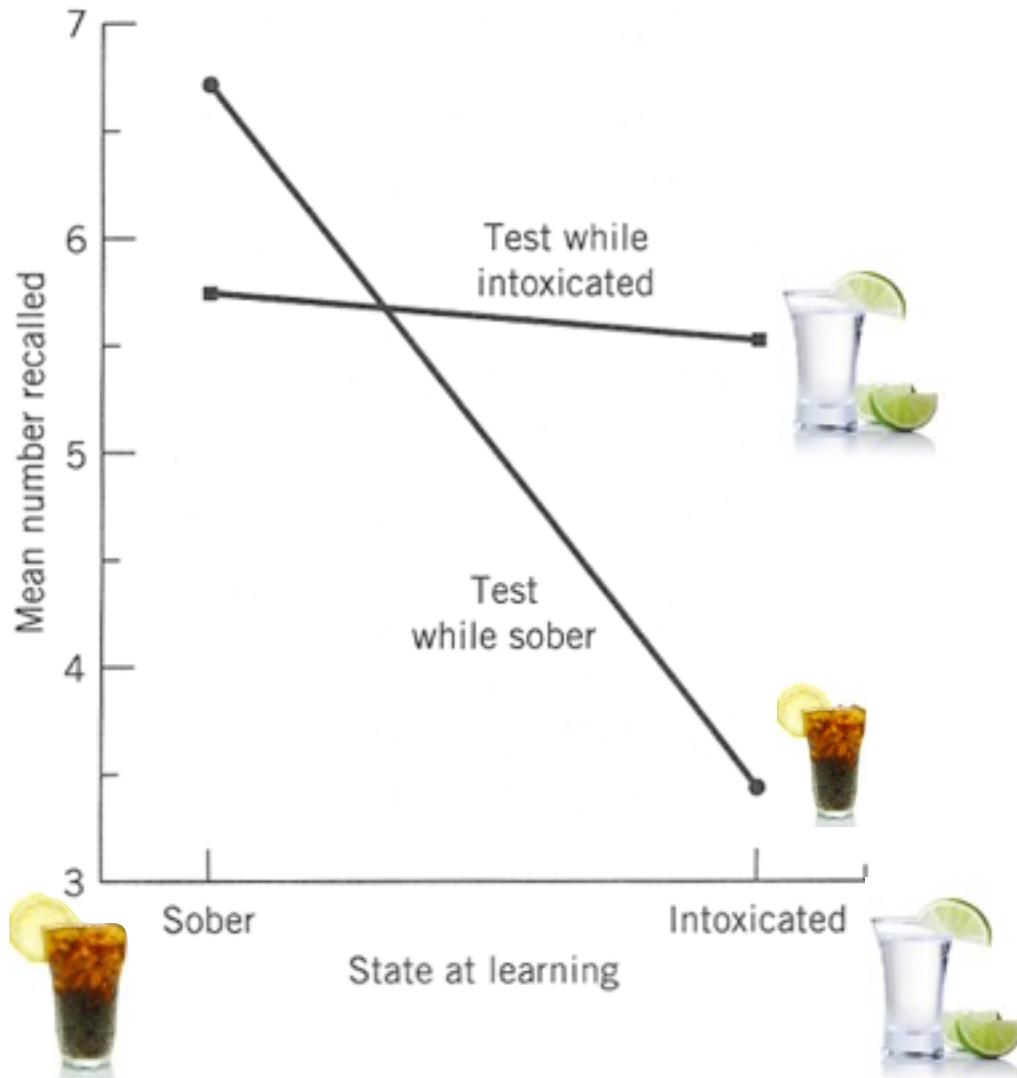
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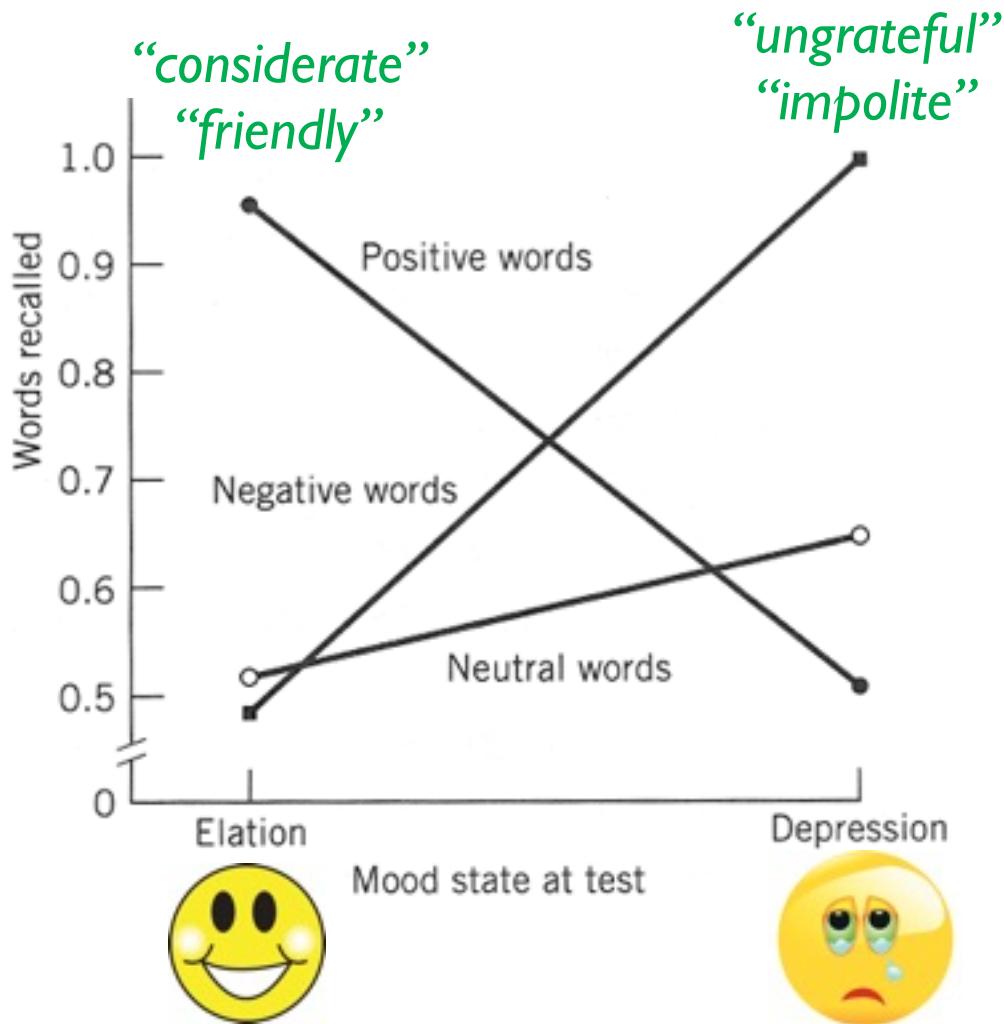


# State-Dependent Memory



- Internal context or states also are associated with learned information
- Internal states serve as useful cues for eliciting retrieval of these memories

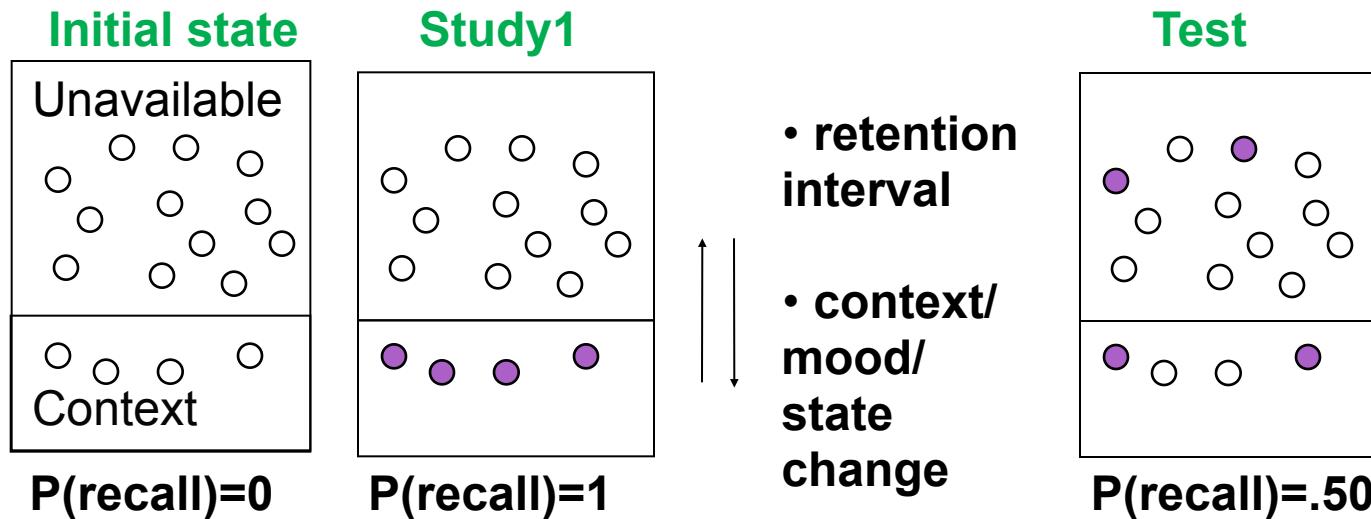
# Mood–Congruent Memory



- Cue-dependent nature of memory has important implications for **mental health**.
- **Internal state biases retrieval toward mood–congruent experiences**, which can create “snowball” effects.

# Principles Governing Retrieval

- The cue-dependent nature of retrieval reveals that the strength of association between cues and the target memory impacts probability of remembering.

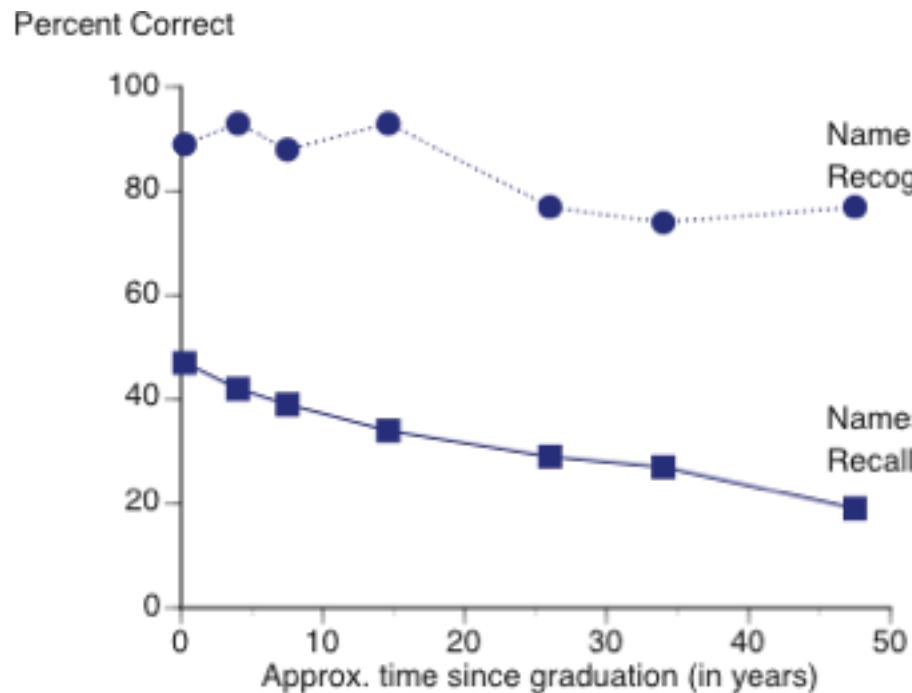


# Outline

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- Principles of Episodic Retrieval
  - Pattern Completion and Reinstatement
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- Recognition Memory

# Type of Test affects Assessment of Memory



Name  
Recognition

Names  
Recalled

► **Name Recognition Test:**  
*Louie Carrillo, Bobby Price*  
“old”                    “new”

► **Name Recall Test:**  
*Remember as many names as possible:*  
“Bobby Hicks”... “Pat Carley”...

- **Memory is better when probed with a recognition test cue than when asked to freely recall names**
- 50 years after HS graduation, **50% decline in recollection**, but only **5-10% drop off in recognition!**

# Recognition Memory Decisions

- Sample scenario:
  - During encoding, present subjects with a list of 50 words
  - During retrieval, present subjects with these same 50 words (**targets**) interleaved with 50 new words (**lures**)
  - Ask subjects to **decide** whether each word is old or new
- How do we classify the subjects' responses?

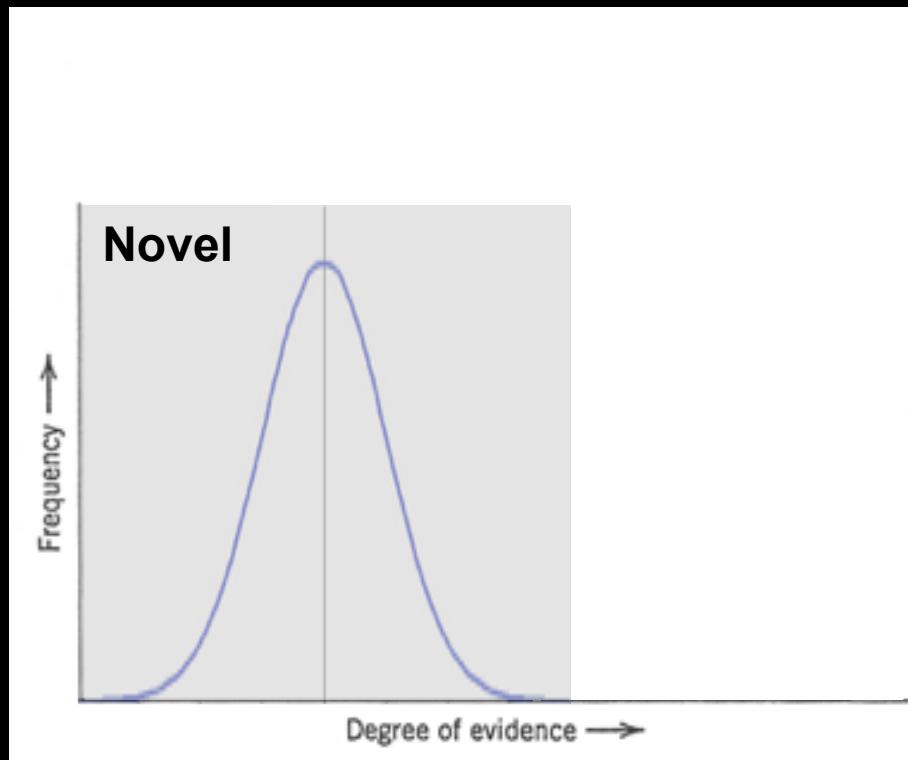
# Response Classification

		Subject response	
		“Old”	“New”
True status	Old	Hit	Miss
	New	False Alarm (FA)	Correct Rejection (CR)

# Recognition Memory: Unitary Memory Signal

## Unitary view

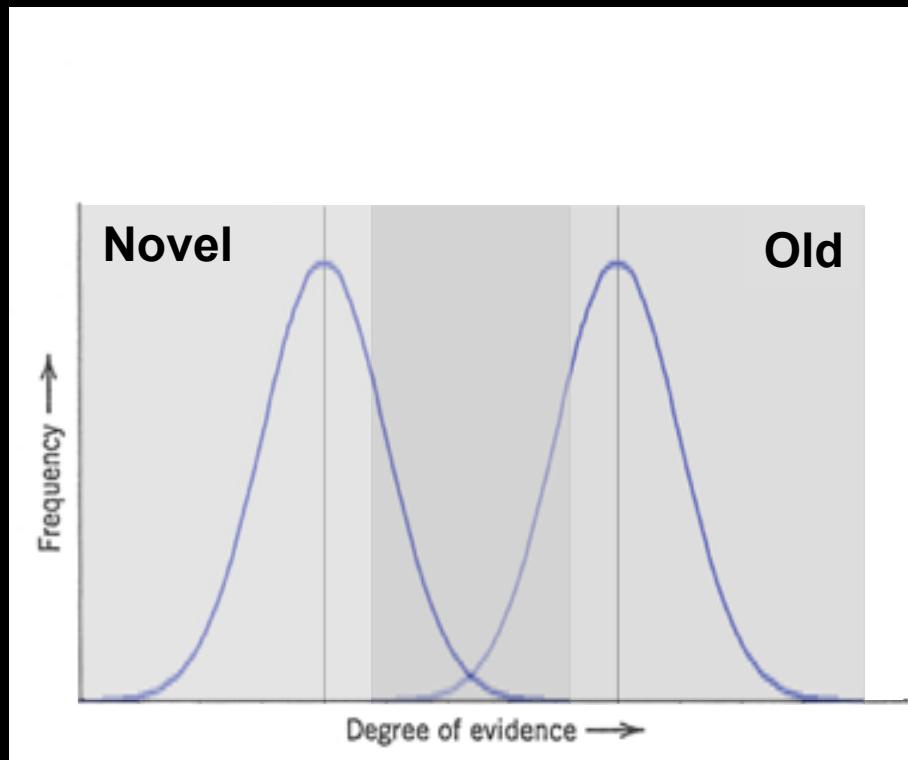
- recognition based on the assessment of memory strength  
[Raaijmakers & Shiffrin (1981), Donaldson (1996), Hirshman & Master (1997)]
- recognition reflects a **signal detection process**



# Recognition Memory: Unitary Memory Signal

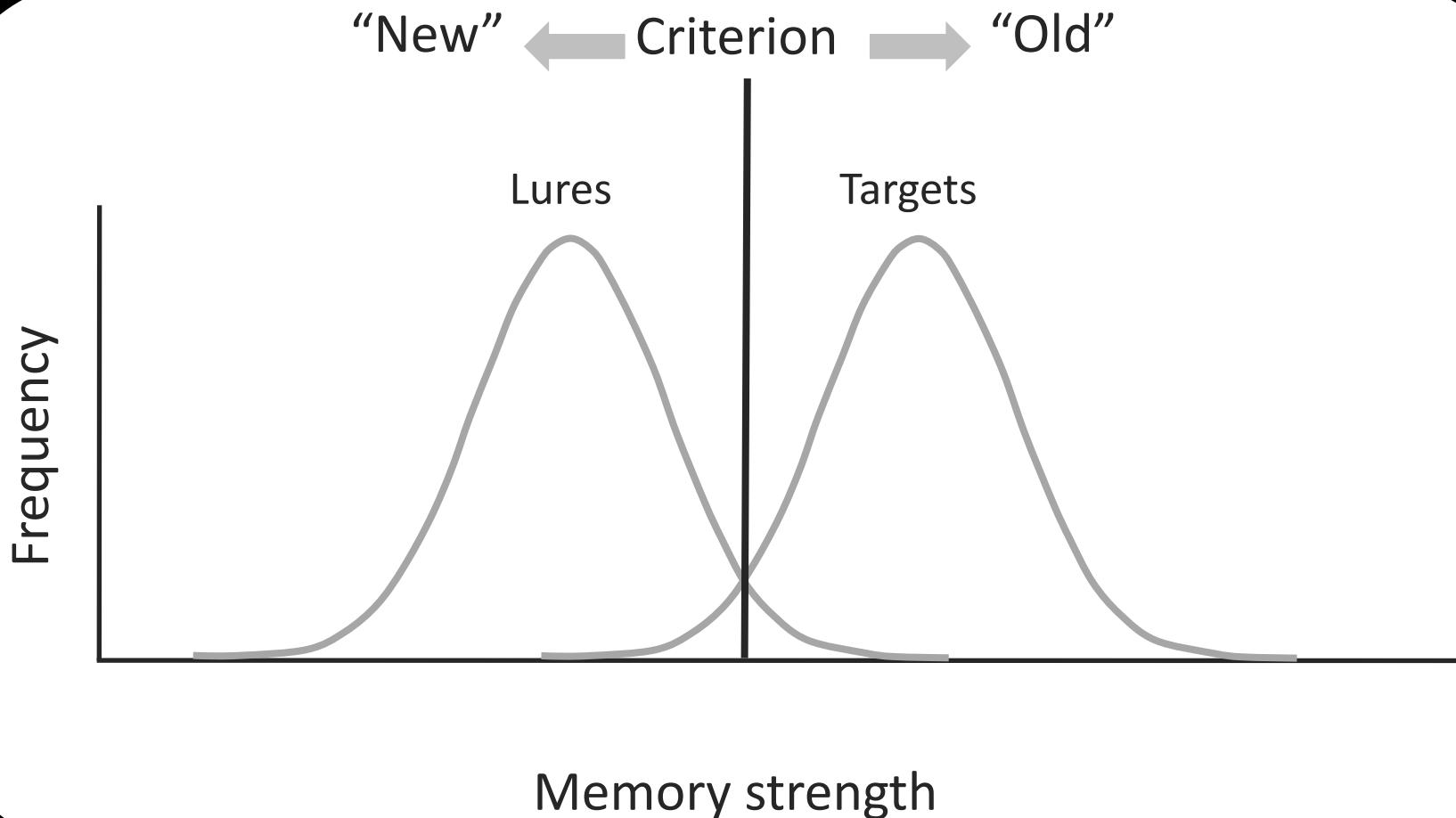
## Unitary view

- recognition based on the assessment of memory strength  
[Raaijmakers & Shiffrin (1981), Donaldson (1996), Hirshman & Master (1997)]
- recognition reflects a **signal detection process**



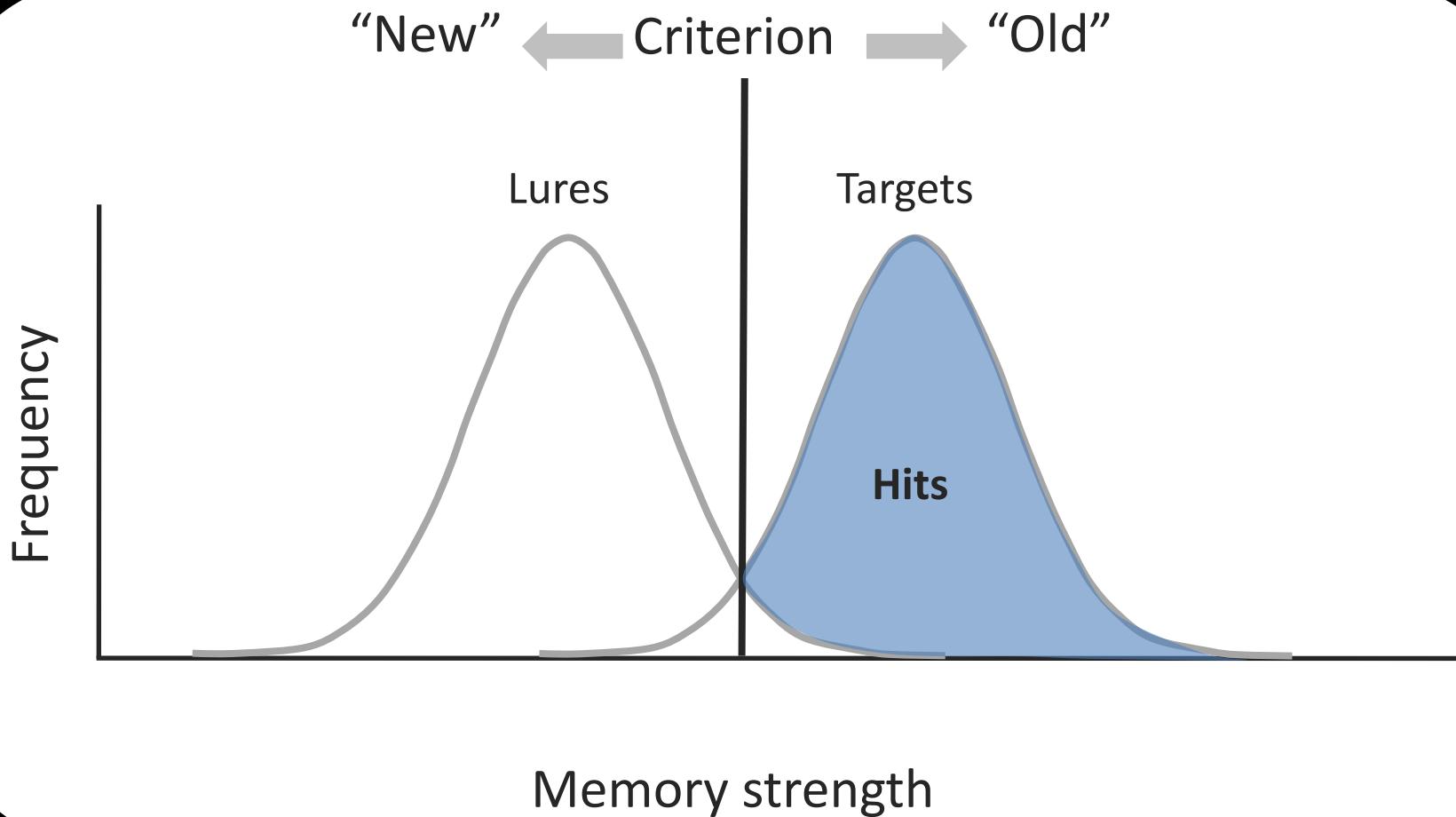
# Recognition Memory: Signal Detection Theory

Recognition is based on our assessment of memory strength



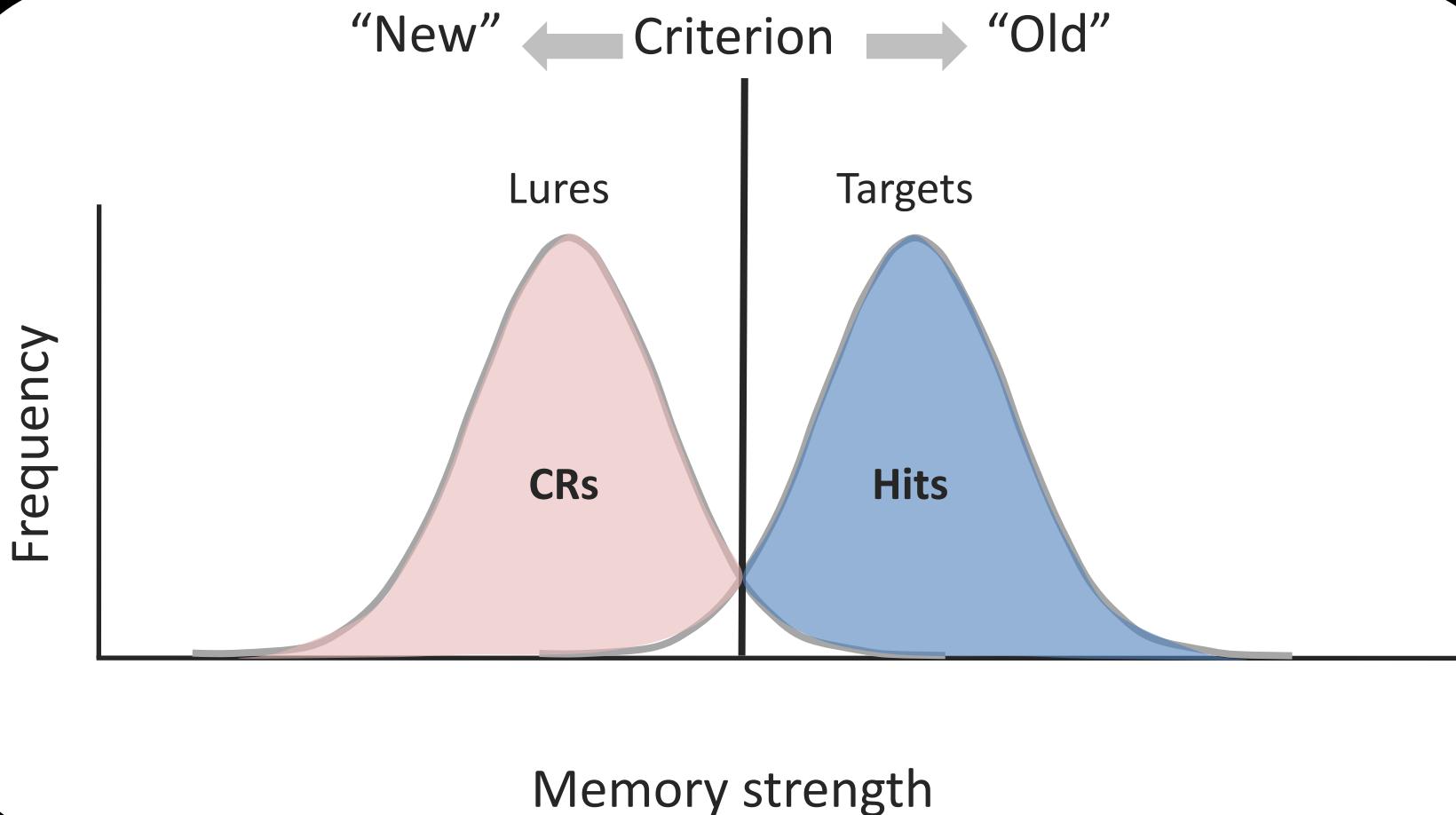
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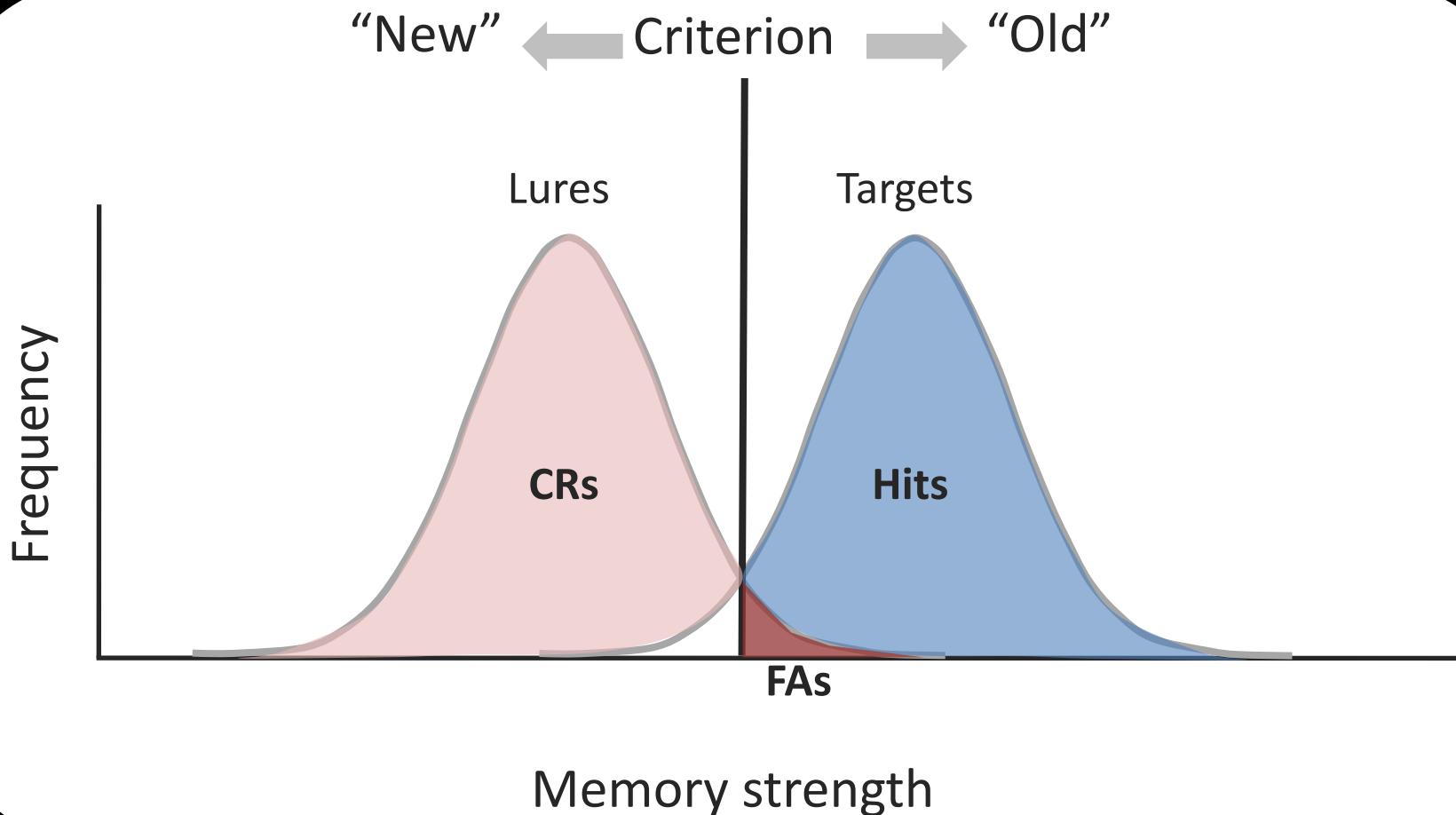
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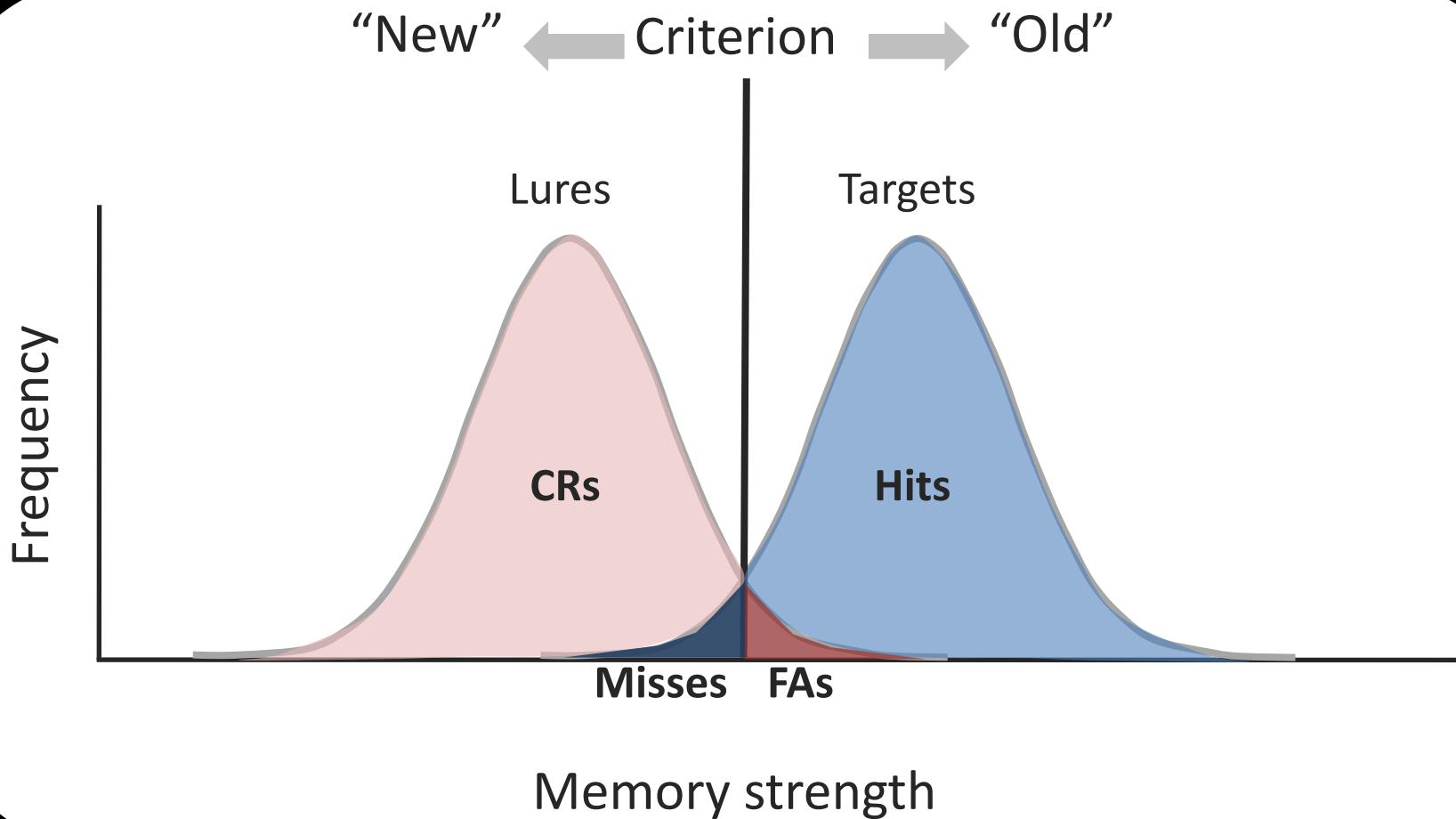
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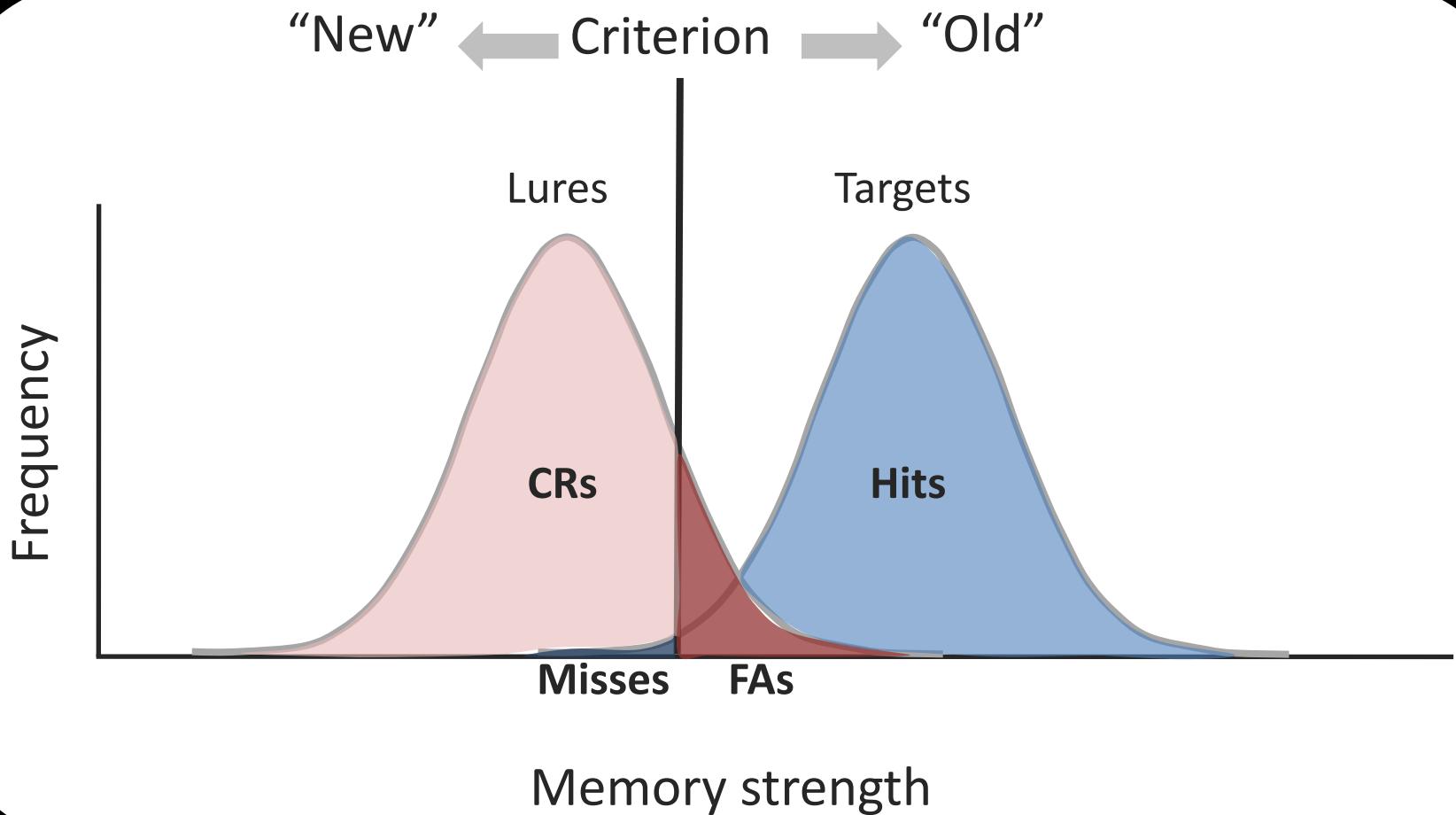
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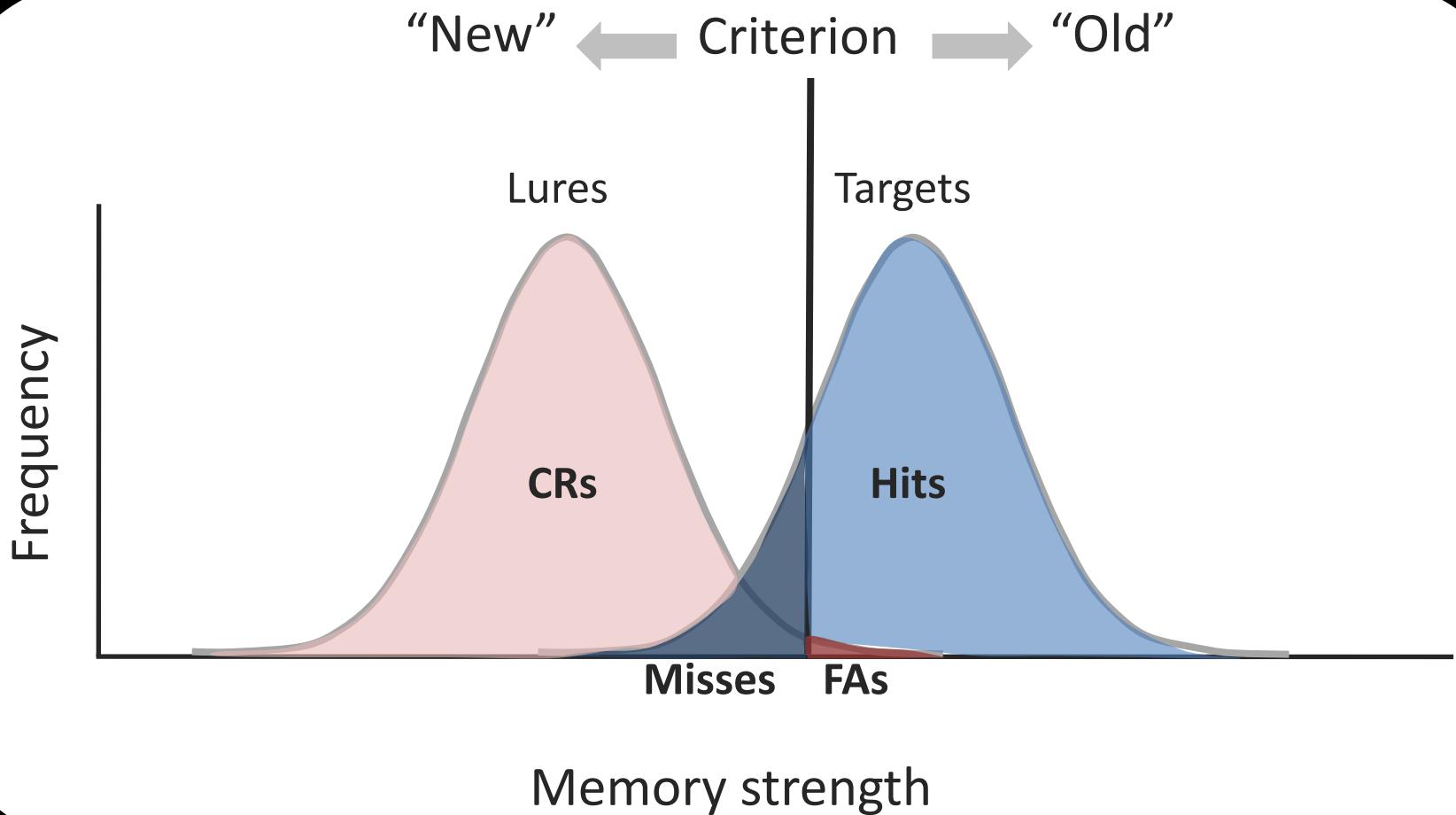
# Recognition Memory: Decision Bias

Where we place our criterion determines our decision bias, ranging from **liberal** to conservative



# Recognition Memory: Decision Bias

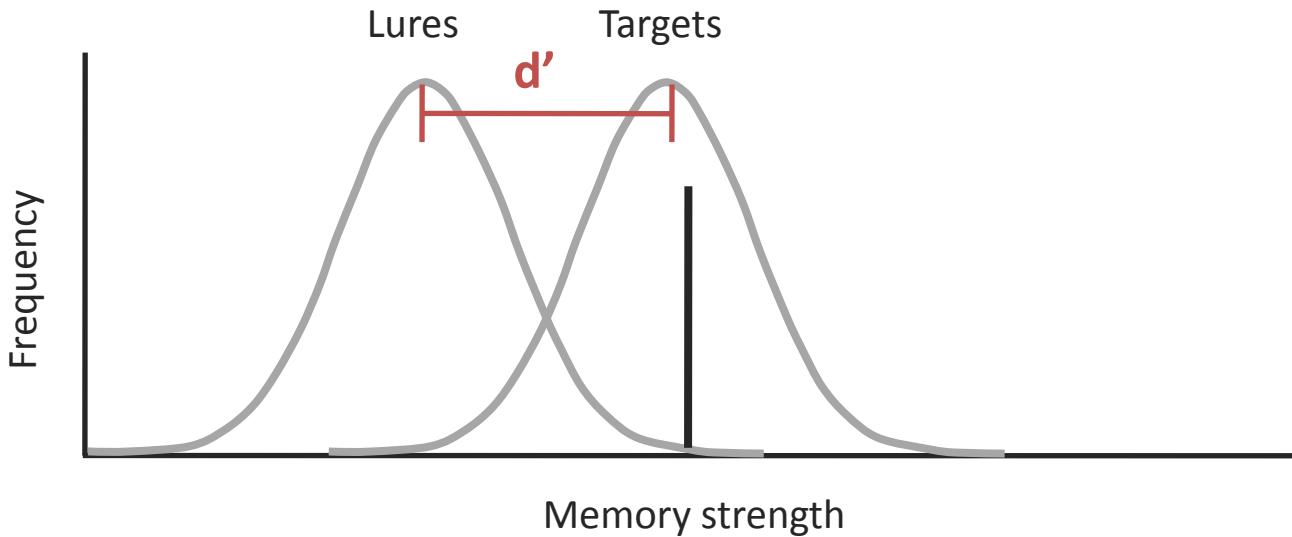
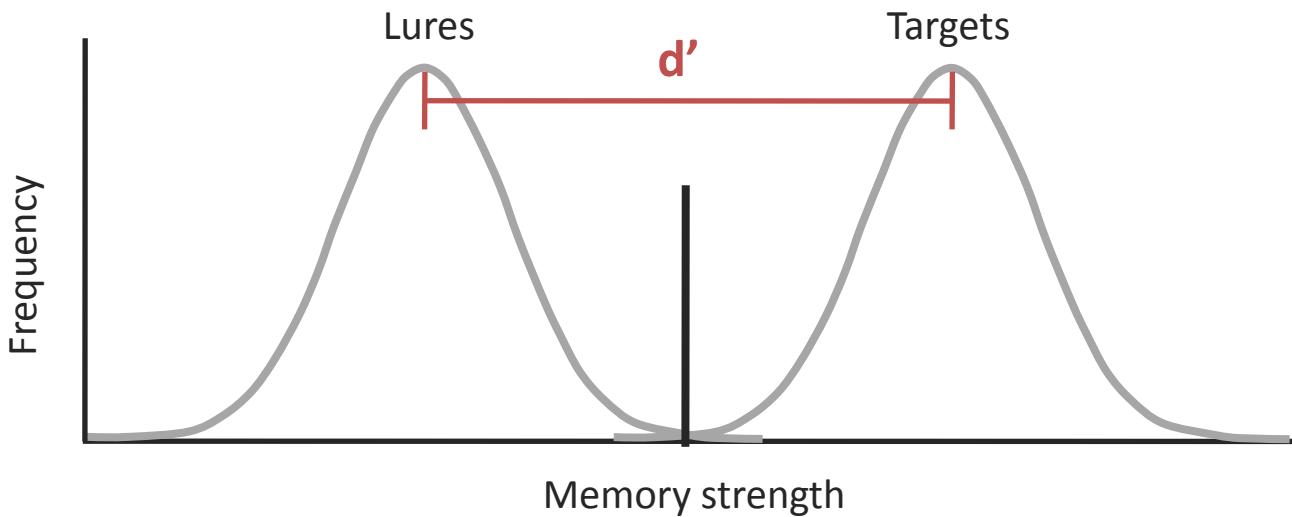
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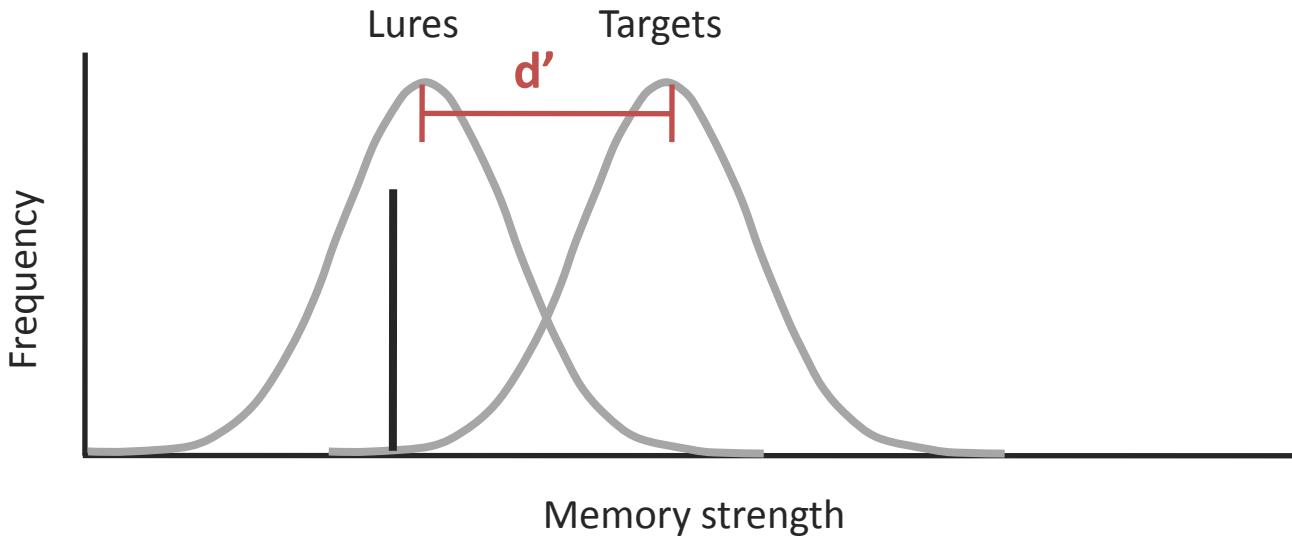
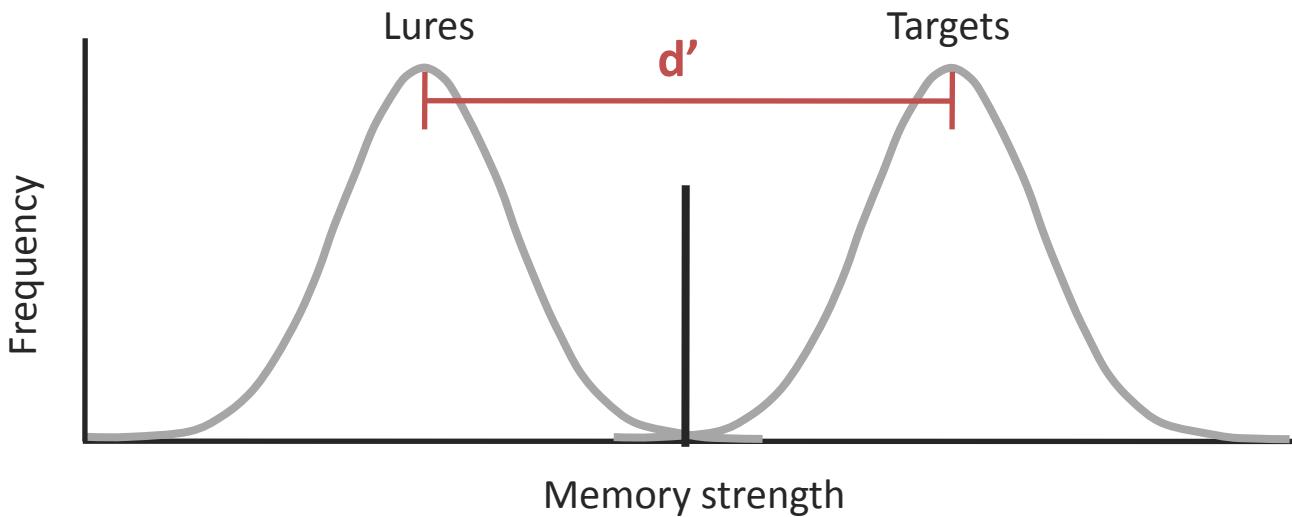
# Recognition Memory: Discriminability vs. Bias

- Importantly, where you place your criterion (i.e., your **bias**) is independent of how good your memory is
- Often the most relevant metric is **discriminability**
  - How far apart are your target and lure distributions
  - Abbreviated as  $d'$  (“d-prime”)

# Recognition Memory: Discriminability



# Recognition Memory: Discriminability



# Recognition Memory: Dual Processes (Two Memory Signals)

## Dual-process view

- recollection and familiarity

[James (1890), Mandler (1980), Atkinson & Juola (1974), Jacoby (1991), Yonelinas (1994)]

### Recollection

- retrieval of event-specific information or details (e.g., context)
- depends on a conjunctive memory trace and underlies recall
- requires attention during encoding
- relatively slow

### Familiarity

- an undifferentiated feeling of having recently encountered an item
- less dependent on attention during encoding
- relatively fast

# Competing Effects of Recollection & Familiarity: “Becoming Famous Overnight”

Study Phase: Read names

Sebastian Weisdorf

Cliff Katz

Nancy Tyler

⋮

*Full or divided-attention*

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Test Phase: Fame Judgment

Jay Woods (n-nf)  
Gary Gilmore (n-f)  
Sebastian Weisdorf (o-nf)

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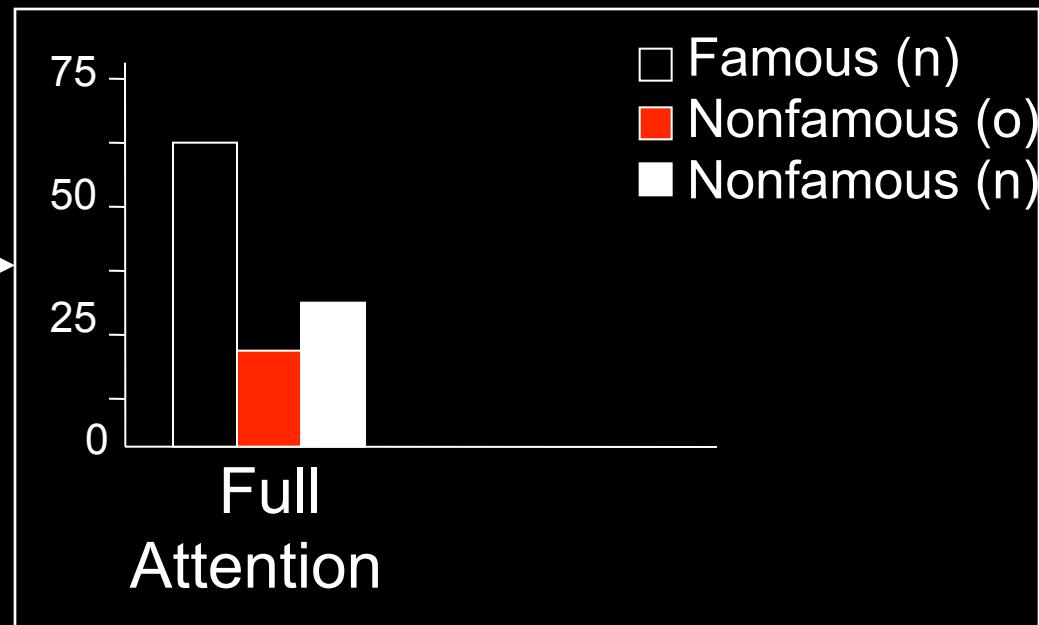
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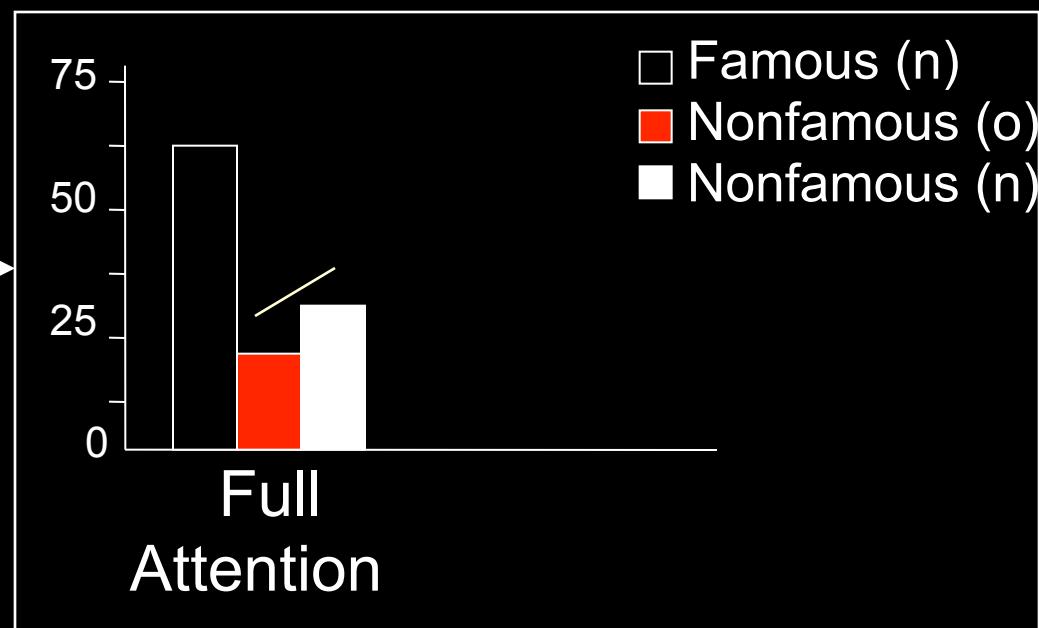
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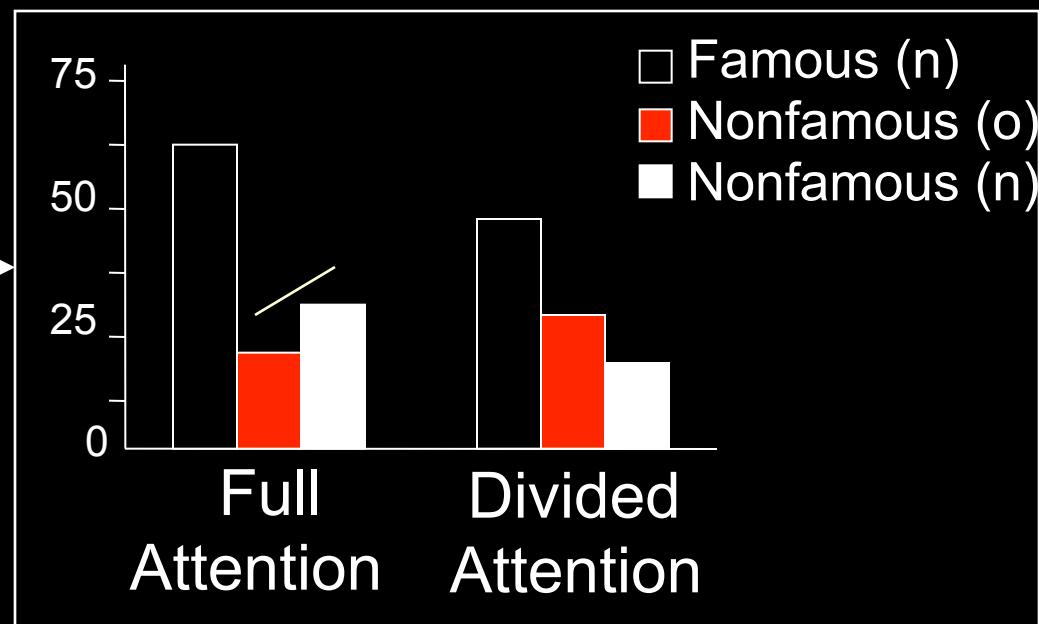
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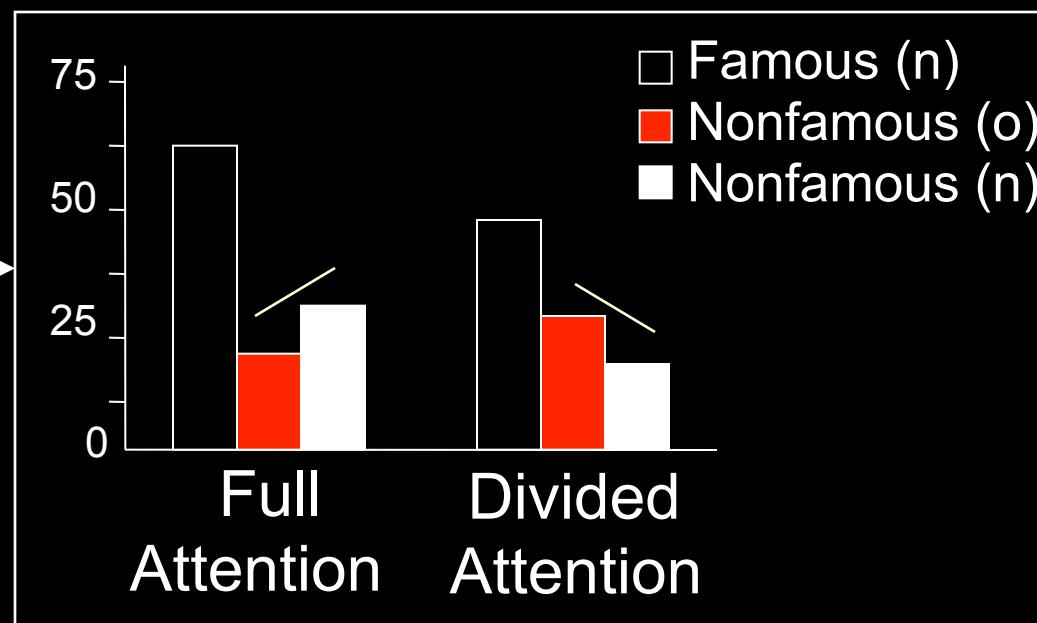
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# Functional Distinctions within the MTL Circuit

