Decomposing the "active" learner: Effects of self-directed control on learning and memory

Doug Markant
New York University

Active vs. passive learning

Potential effects of “active” learning

Data-driven effects: What is the *outcome,* in terms of the data experienced during learning?
Collect more informative data than is typically experienced
Expose data that is unavailable from passive observation
Generate data that tests current hypothesis

Potential effects of “active” learning

Data-driven effects: What is the *outcome,* in terms of the data experienced during learning?	**Decision-driven effects:** What processes are related to the *execution* of decisions?
Collect more informative data than is typically experienced	Recruitment of additional processes (e.g., prediction, explanation, etc.)
Expose data that is unavailable from passive observation	Improved attentional coordination with flow of experience
Generate data that tests current hypothesis	Inherent rewards or engagement associated with free choice and exploration

Study 1: Selection vs. reception in perceptual category learning

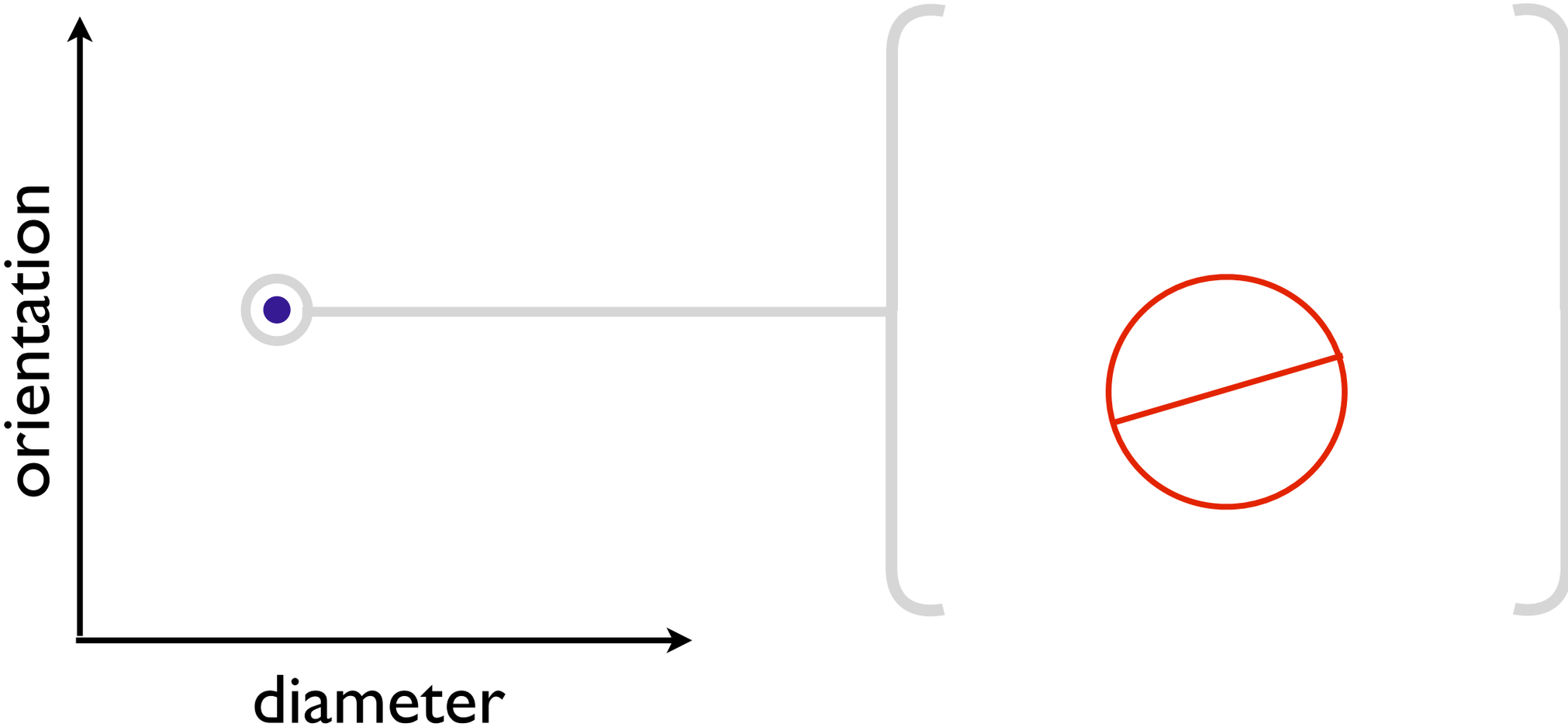
Markant, D. and Gureckis, T. (in press). Is it better to select or receive? Learning via active and passive hypothesis testing. JEP:GEN.

Selection vs. reception

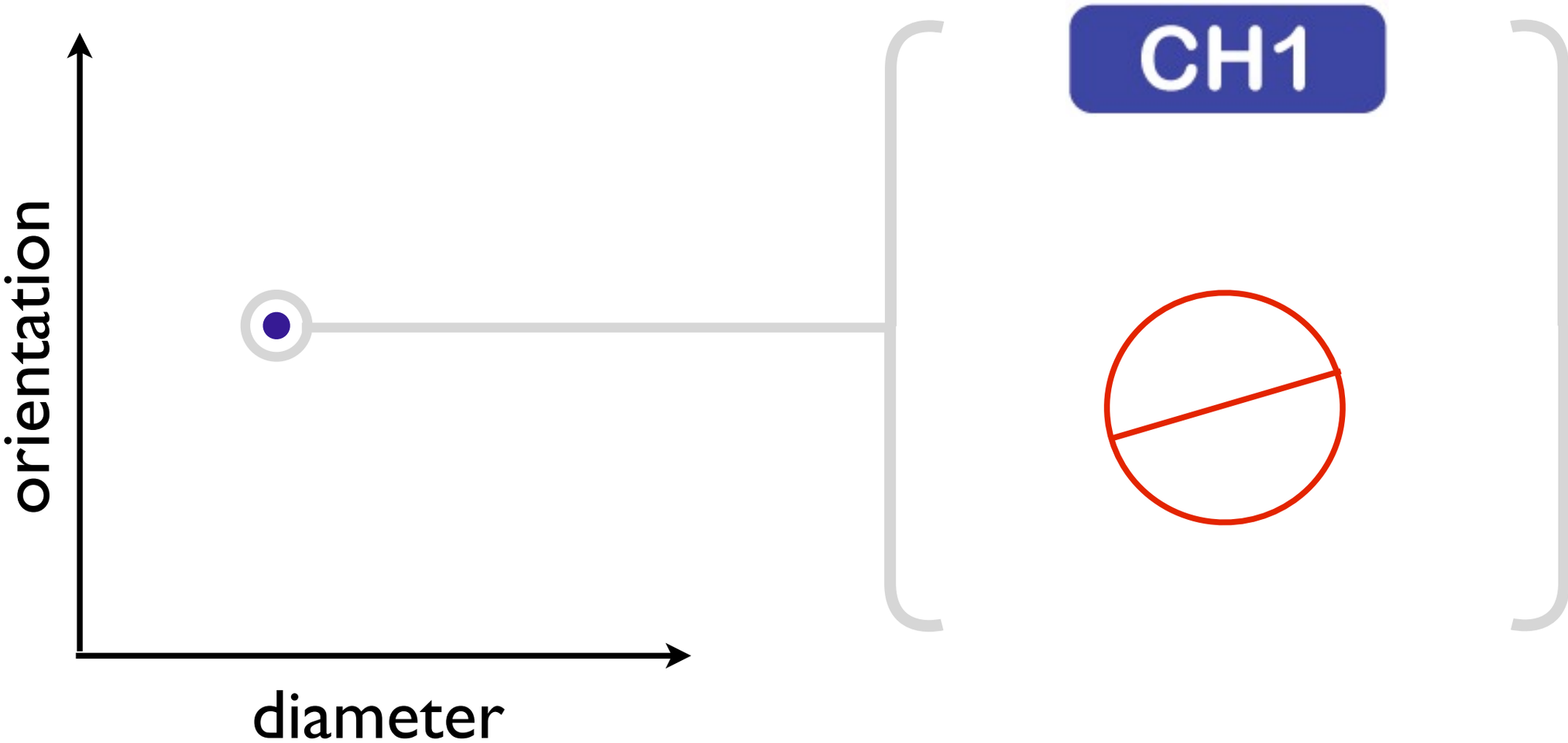
- Long recognized as a basic distinction in concept learning (Bruner, Goodnow, Austin, 1956)
- Selection has most often been studied in context of hypothesis testing (e.g., card selection task, rule discovery task, diagnostic reasoning)
- Reception has been dominant mode of learning in many experimental traditions related to learning and memory

Antenna learning

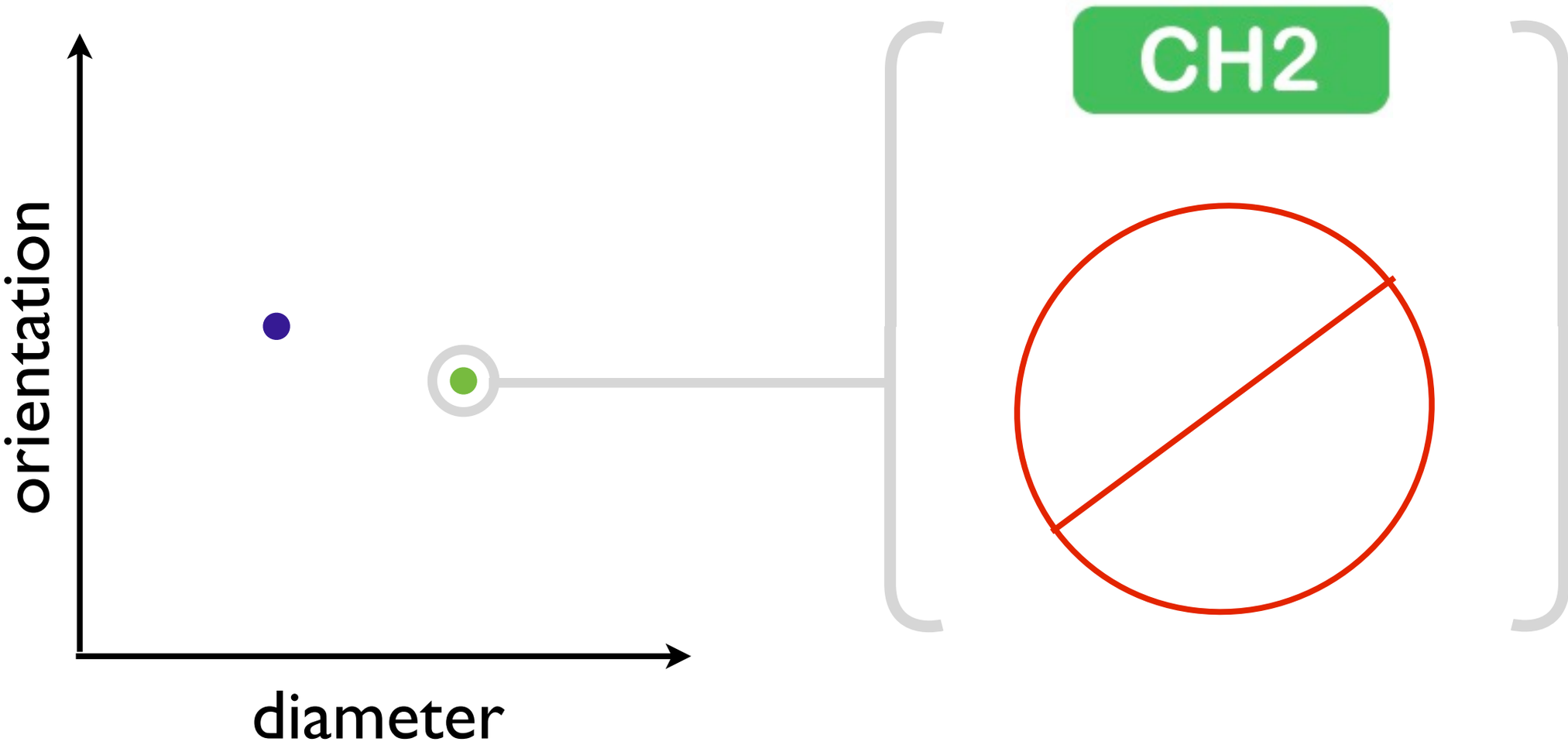
Stimuli



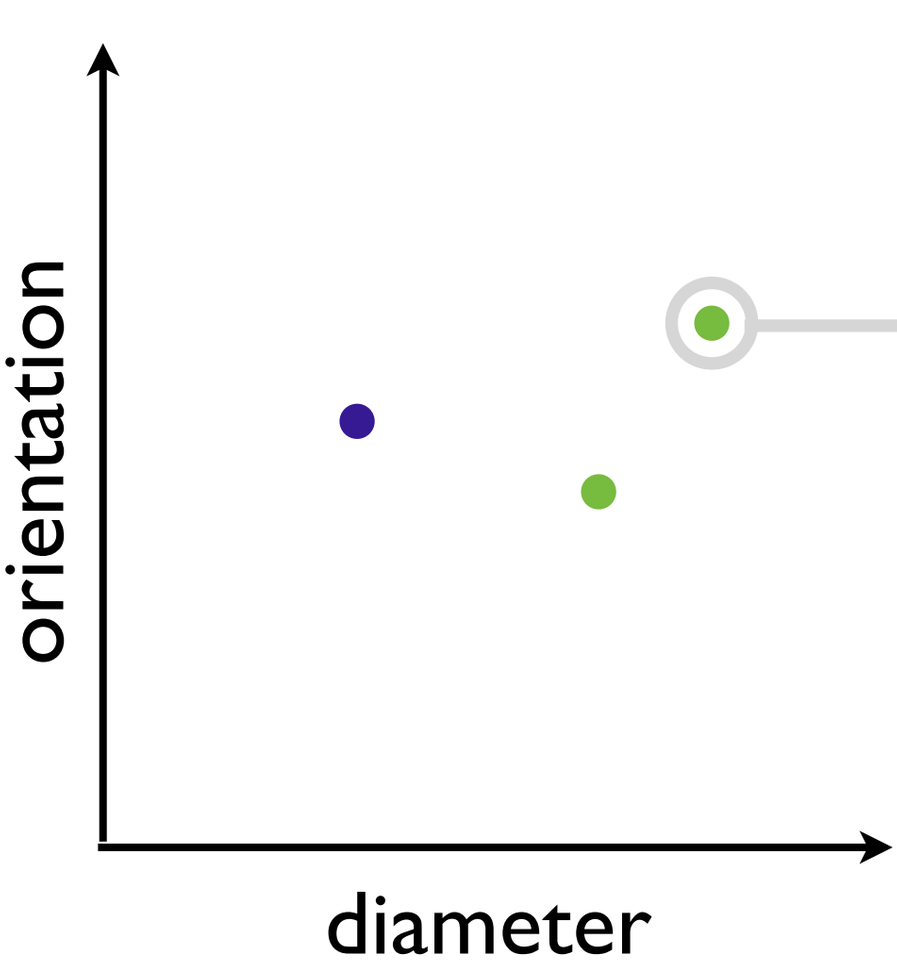
Stimuli

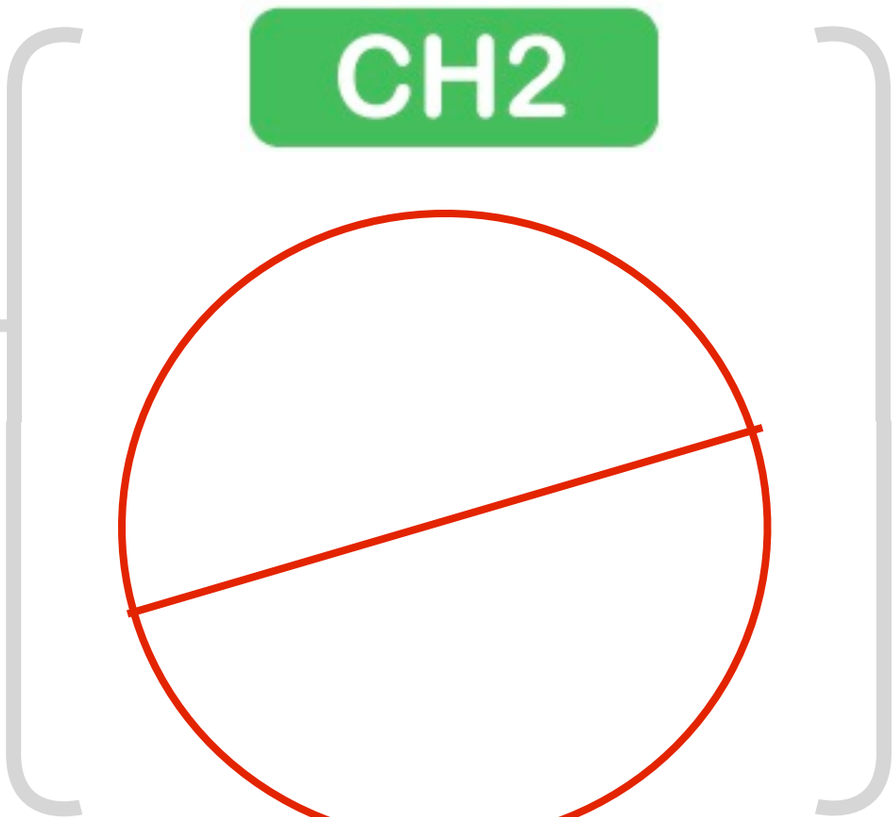


Stimuli

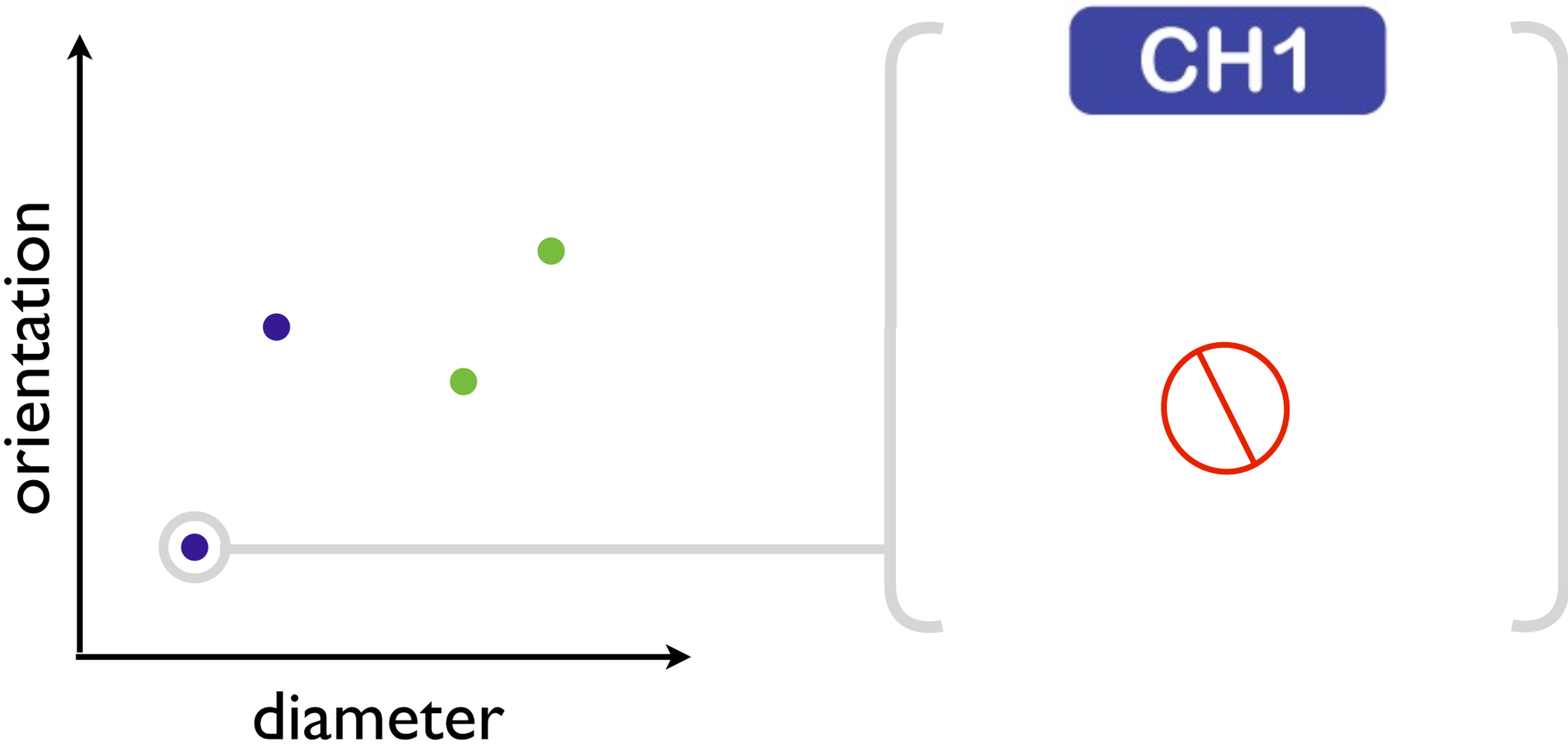


Stimuli

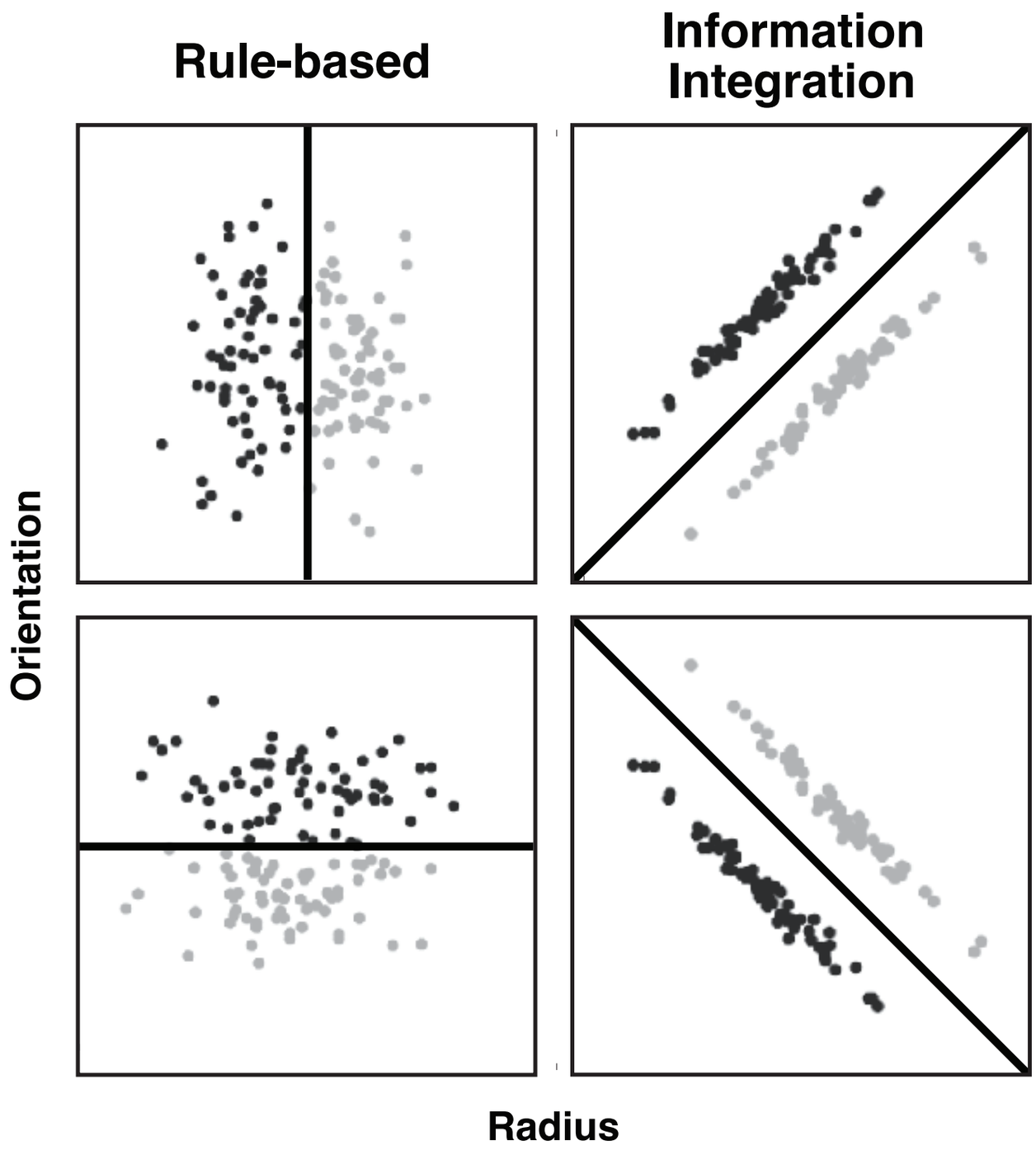




Stimuli

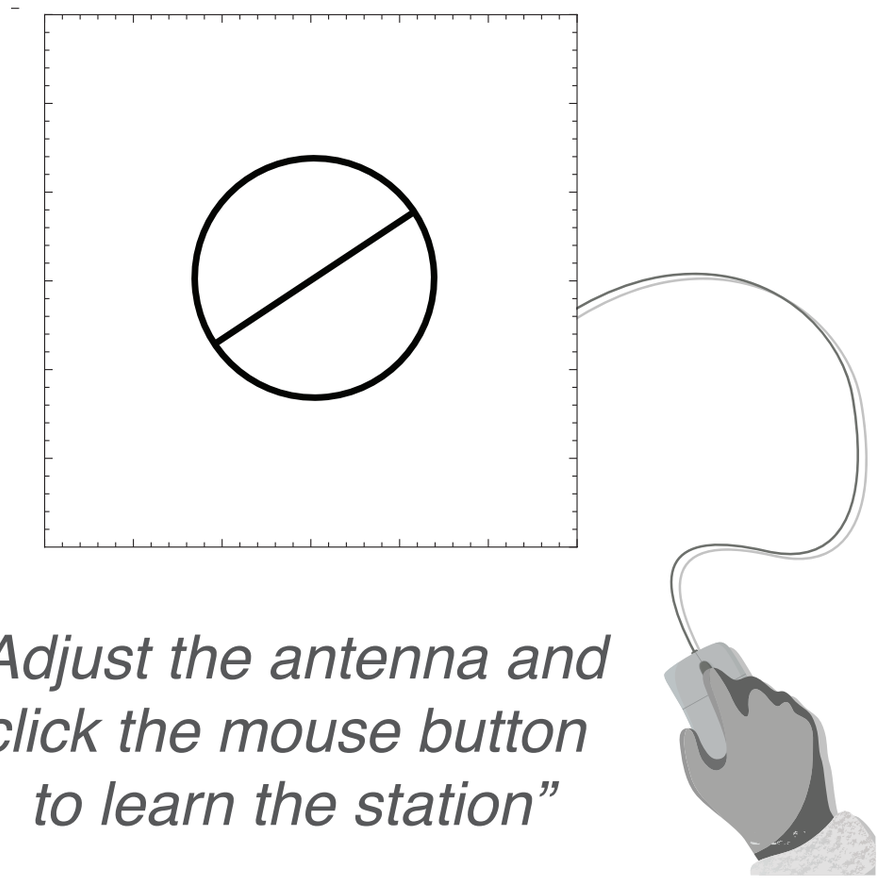


Reception condition



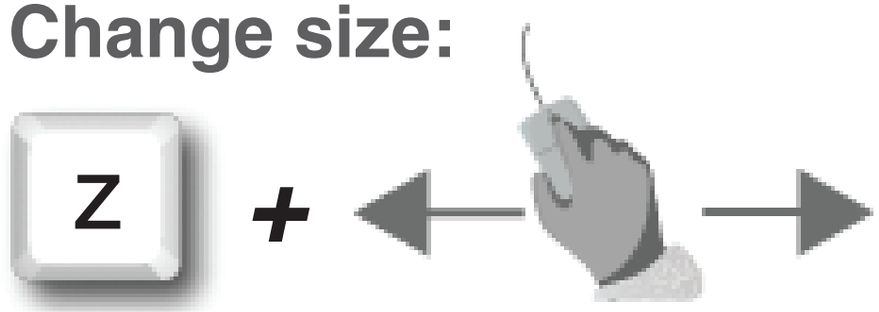
Ashby, F.G, Maddox, W.T., and Bohil, C.J (2002), Memory & Cognition

Selection condition

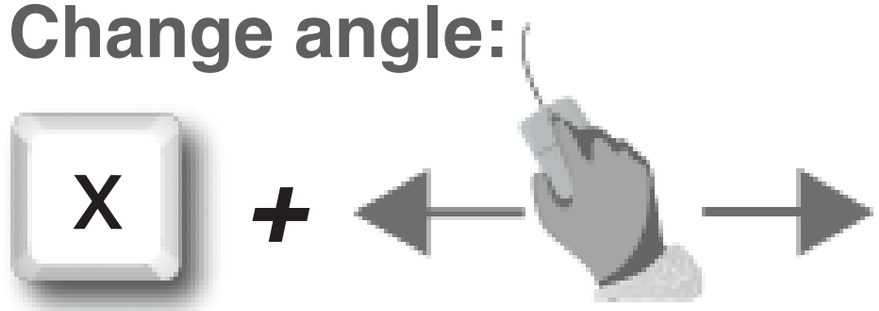


“Adjust the antenna and click the mouse button to learn the station”

Change size:



Change angle:

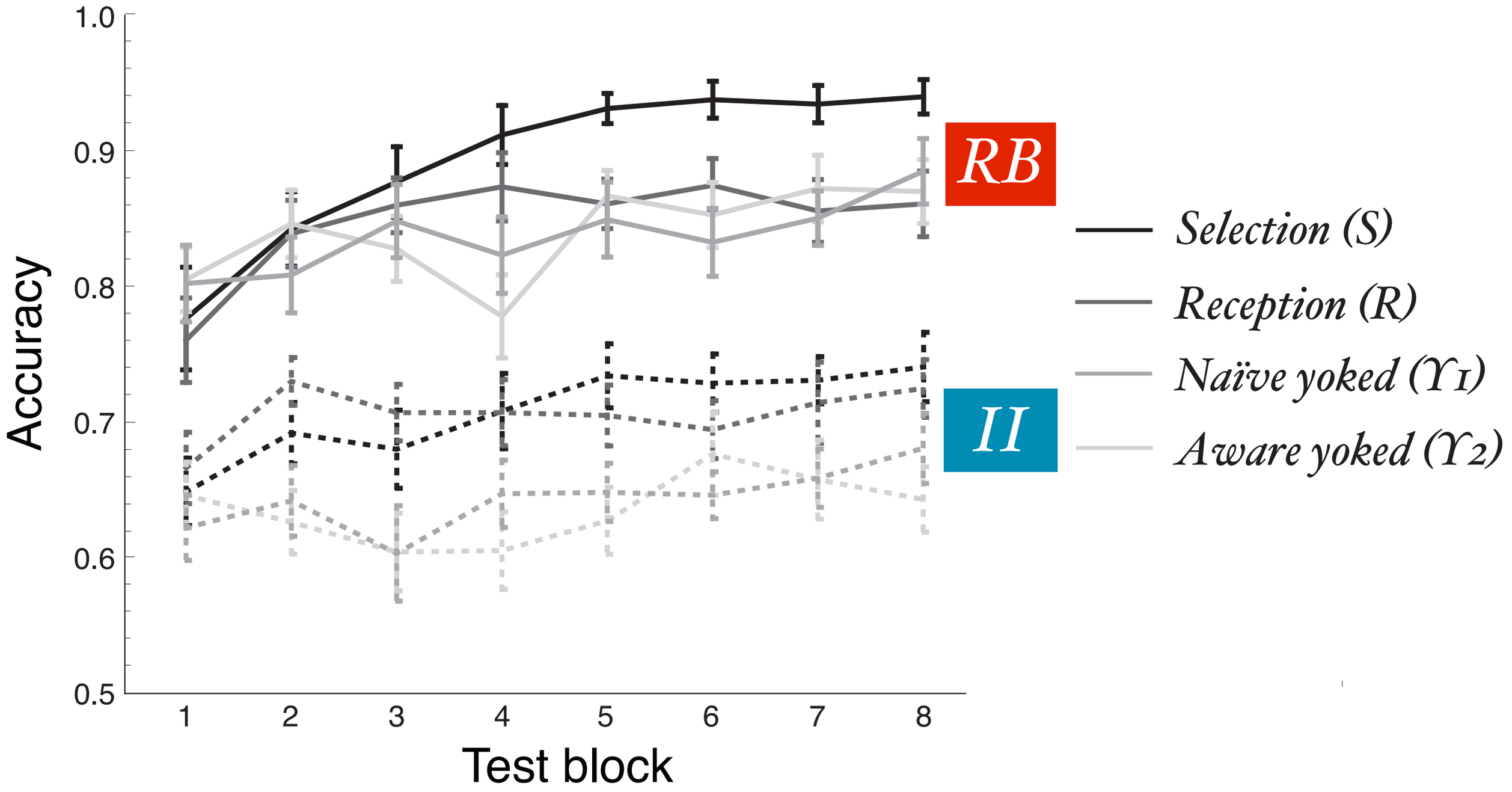


Design

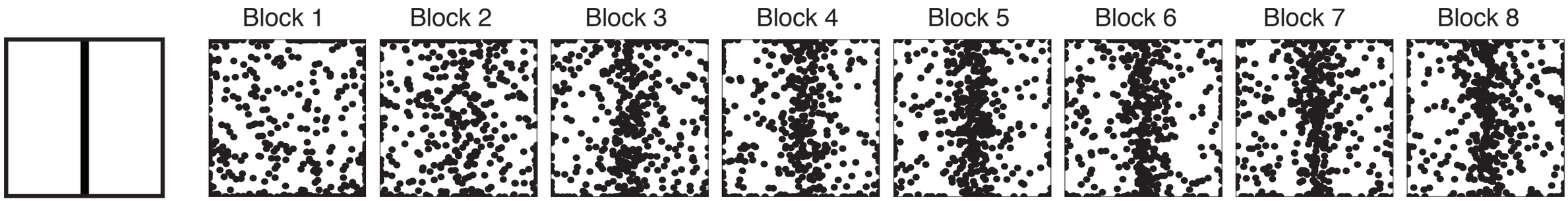
- Conditions
    - Reception
    - Selection
    - Yoked reception (Naive)
    - Yoked reception (Aware)
- Observational training
- 8 training blocks, 16 items each
- 8 test blocks, 32 items each

Classification performance

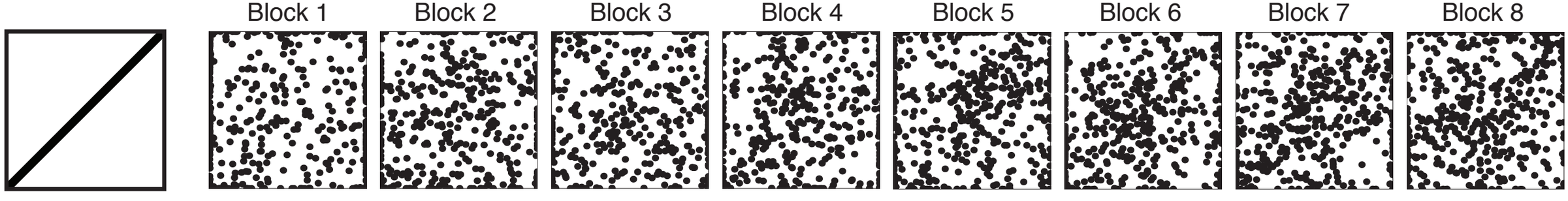
Accuracy by test block



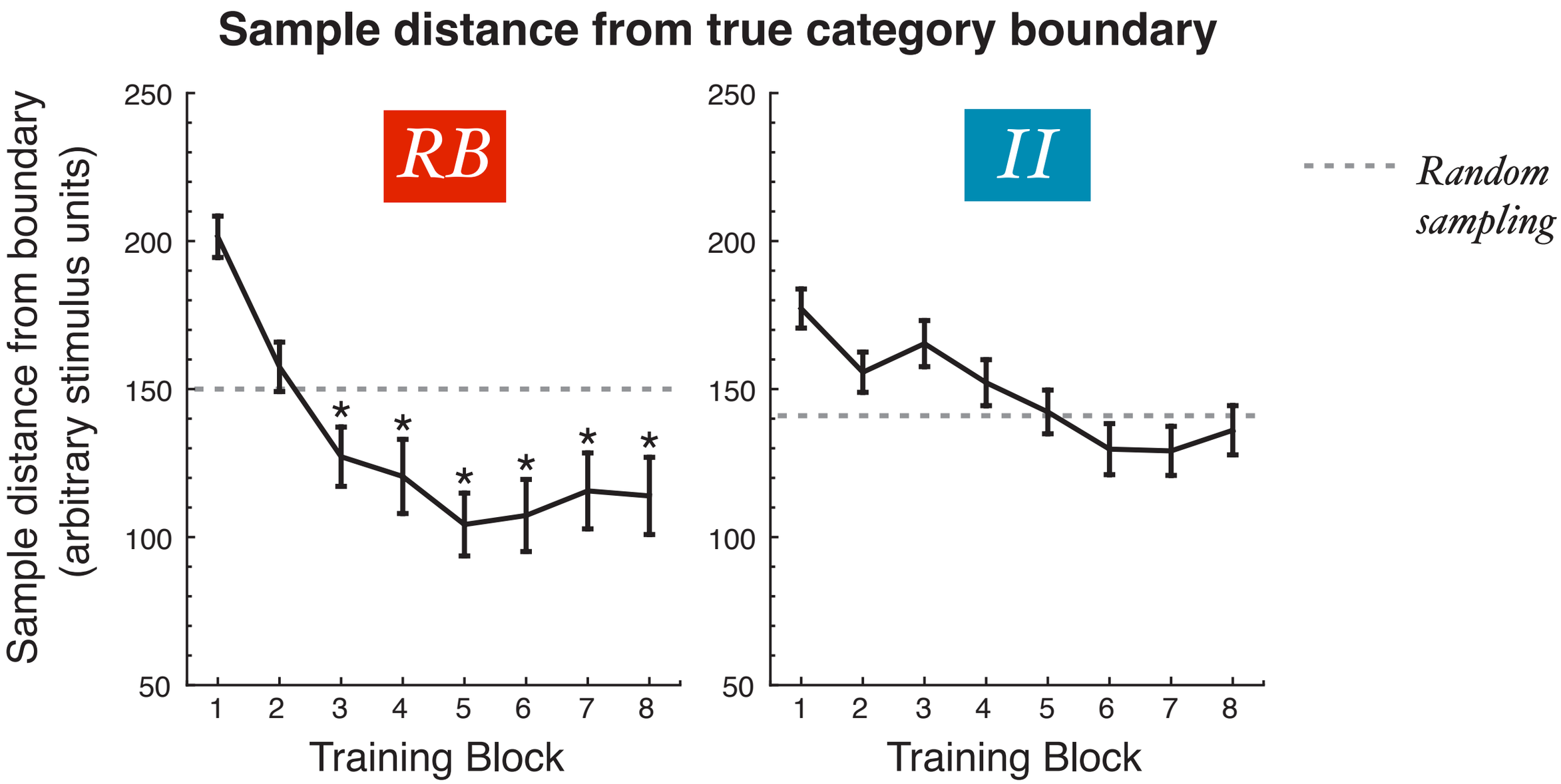
Selections (*RB*)



Selections (*II*)

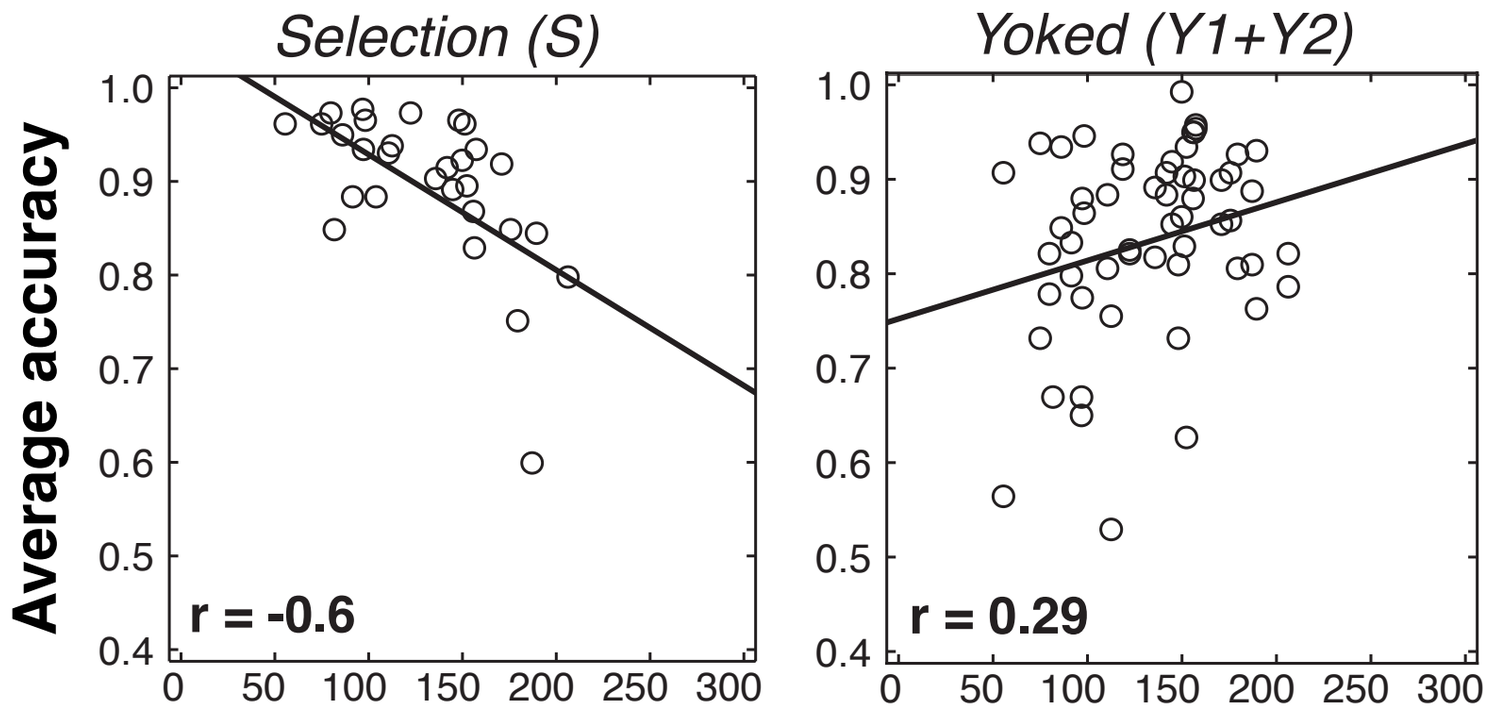


Sampling behavior

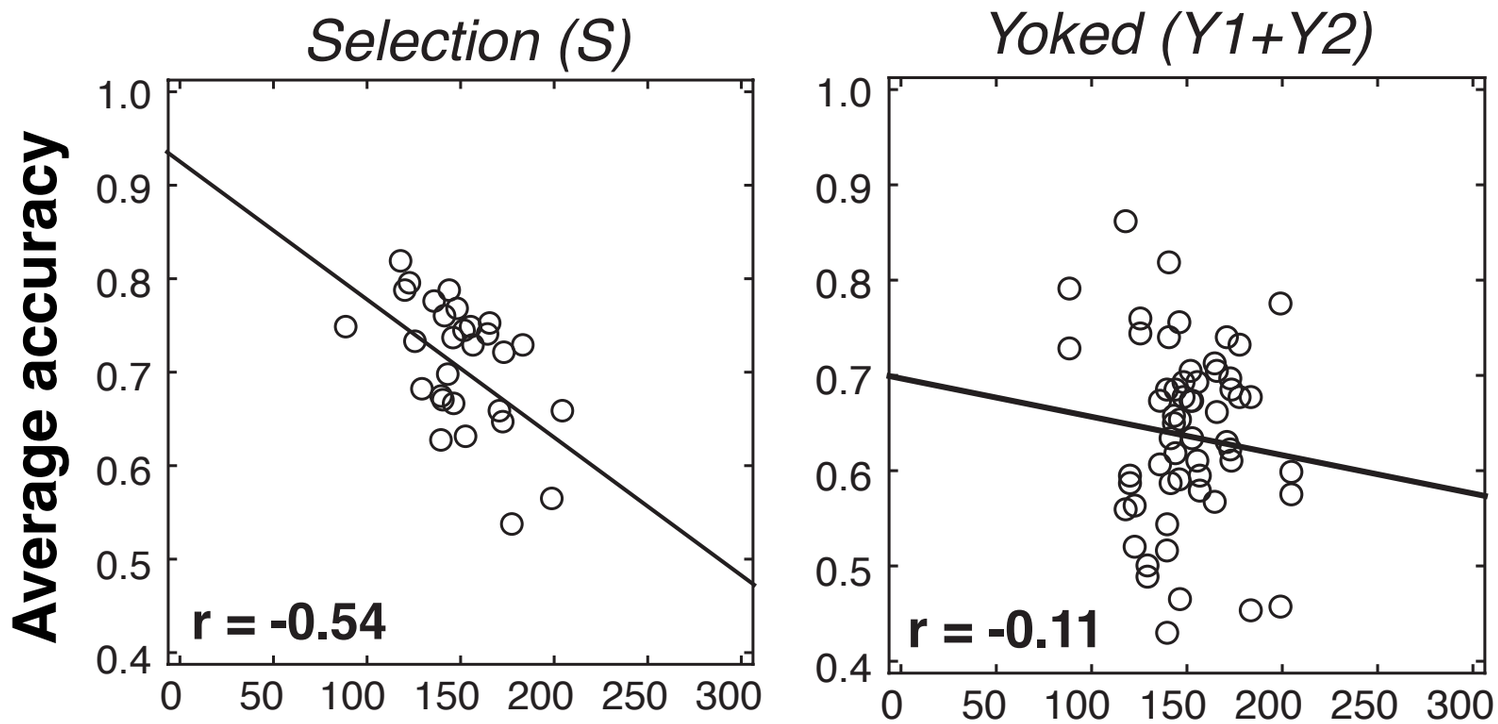


Relating selections to learning

RB

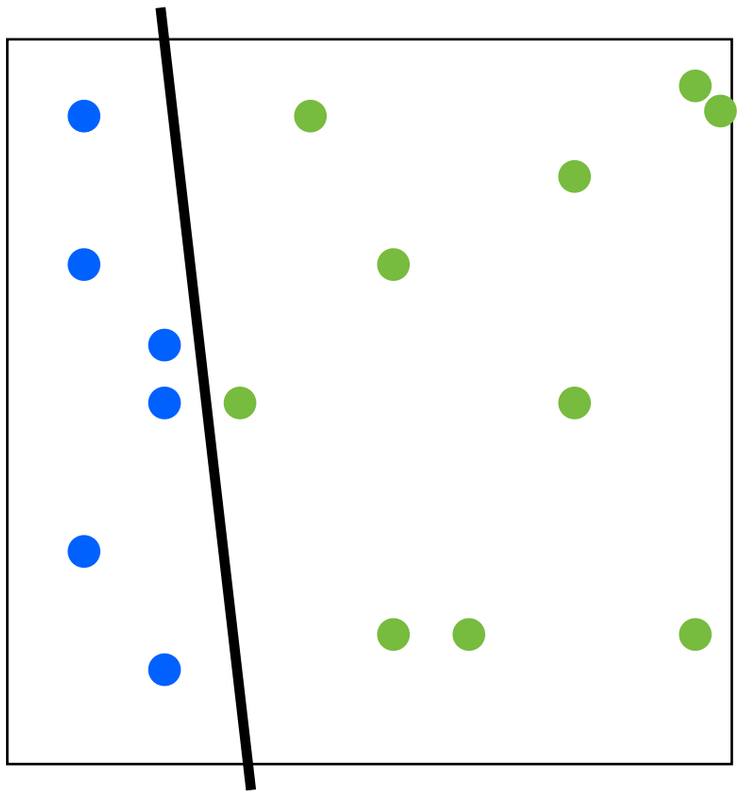


II

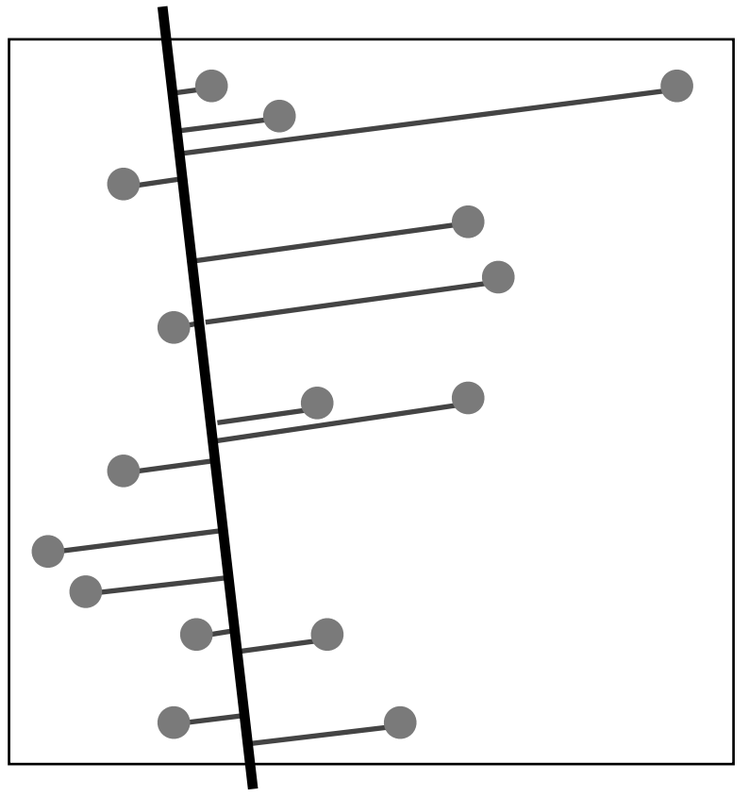


“Subjective” sample distance

Responses during test block

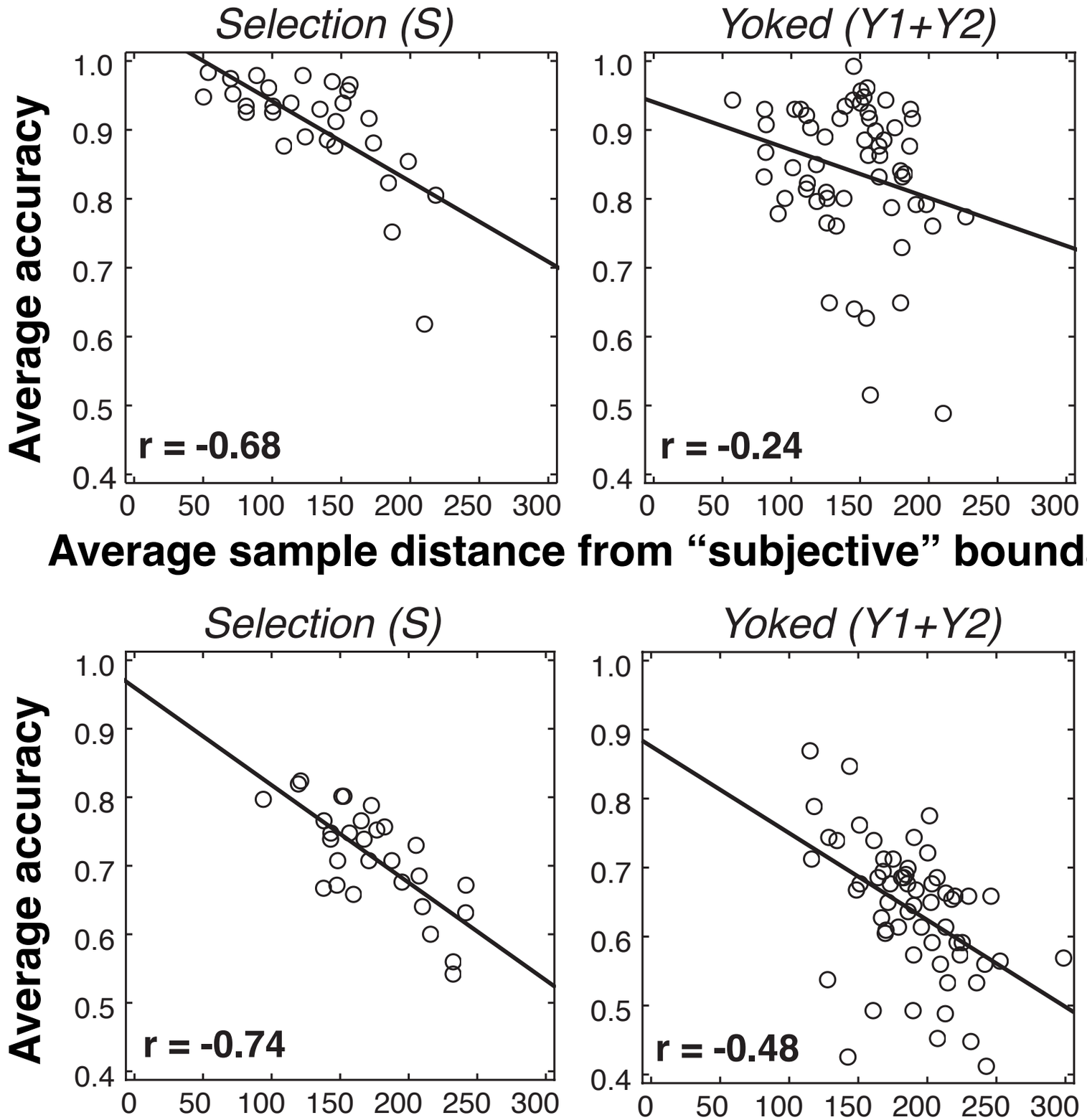


Items selected/observed during next training block



“Subjective” sample distance

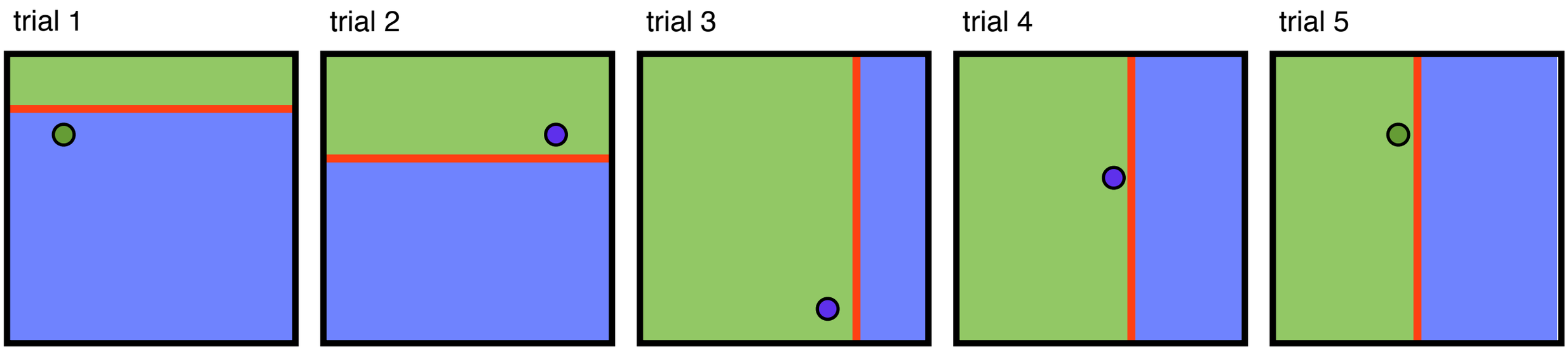
RB



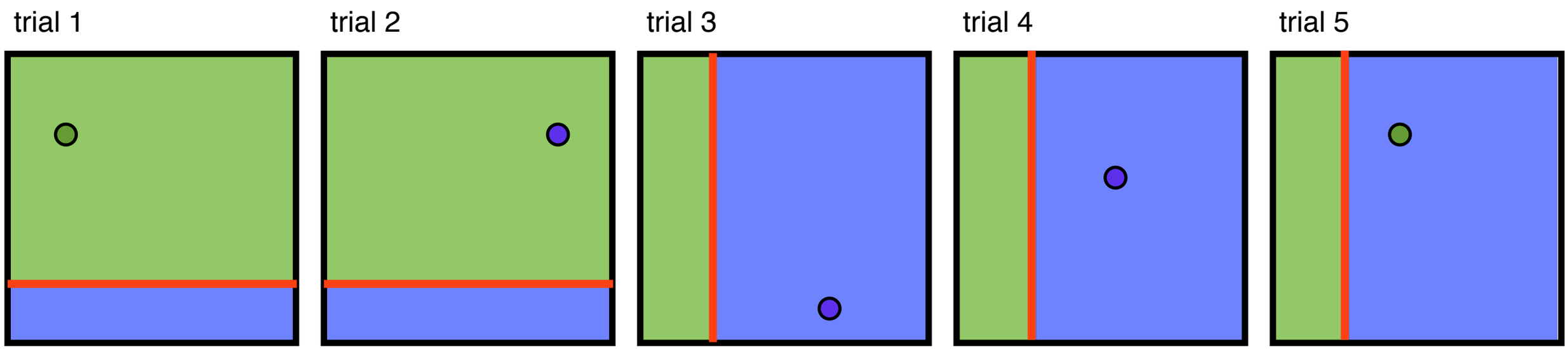
II

Hypothesis-dependent sampling bias

Selection participant



Yoked participant



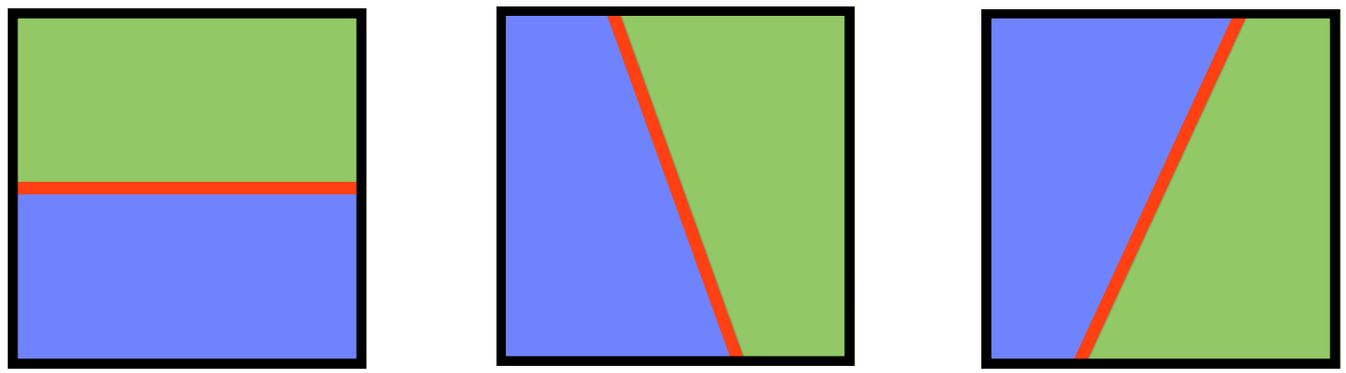
Model

Hypothesis representation

$$h^t = (\theta^t, b^t)$$

Prior

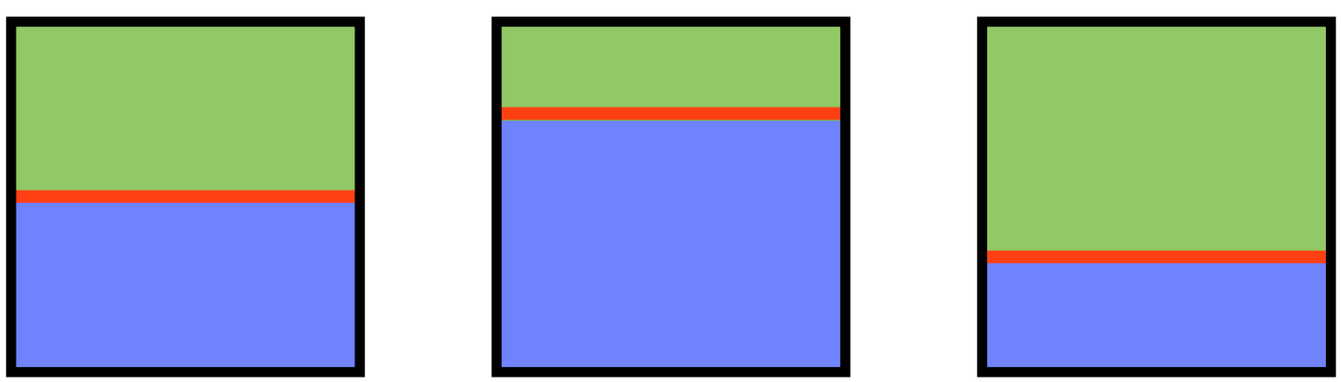
θ : Orientation of boundary



Hypothesis generation and updating

Item Memory

b : Offset of boundary from center



Hypothesis-dependent sampling bias

Model

Hypothesis representation

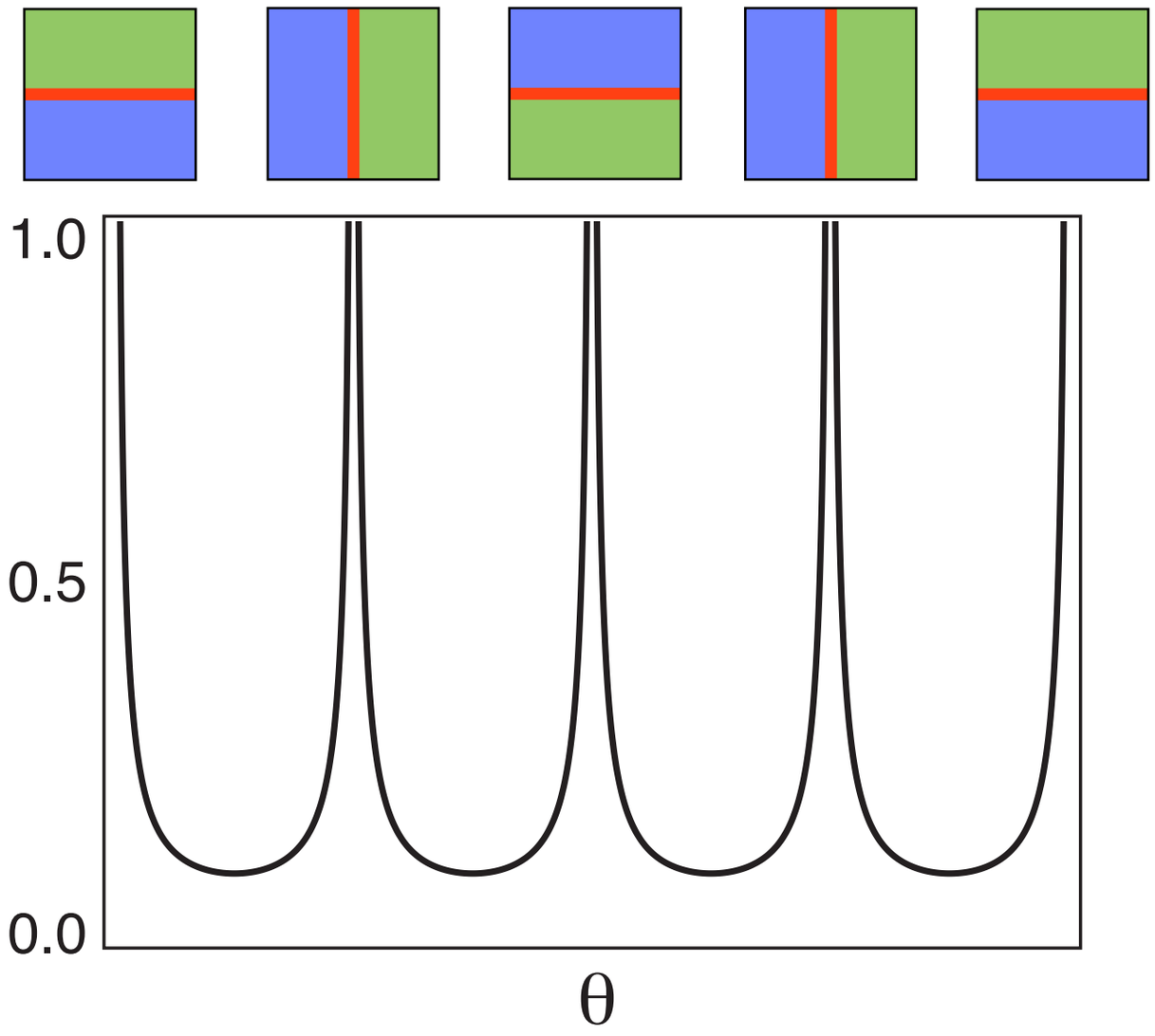
Prior α

Hypothesis generation and updating

Item Memory

Hypothesis-dependent sampling bias

Prior distribution over rule orientation (θ)



α : controls strength of preference for unidimensional rules

Model

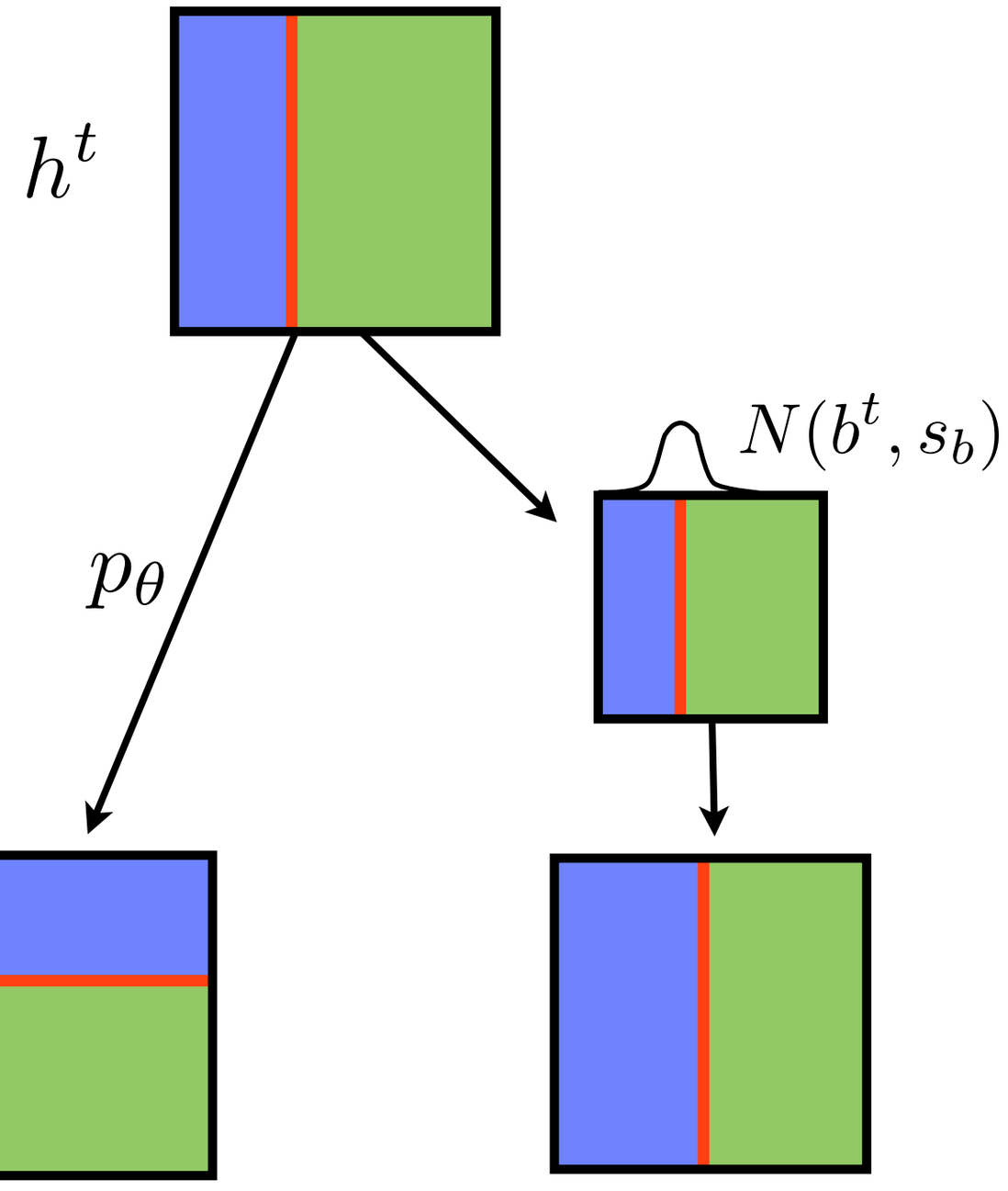
Hypothesis representation

Prior α

Hypothesis generation and updating p_θ s_b

Item Memory

Hypothesis-dependent sampling bias



p_θ : probability of modifying θ

s_b : width of proposal distribution for b

Model

Hypothesis representation		n : Number of recent observations stored in memory
Prior	α	
Hypothesis generation and updating	p_θ s_b	
Item Memory	n	
Hypothesis-dependent sampling bias		

Model

Hypothesis representation

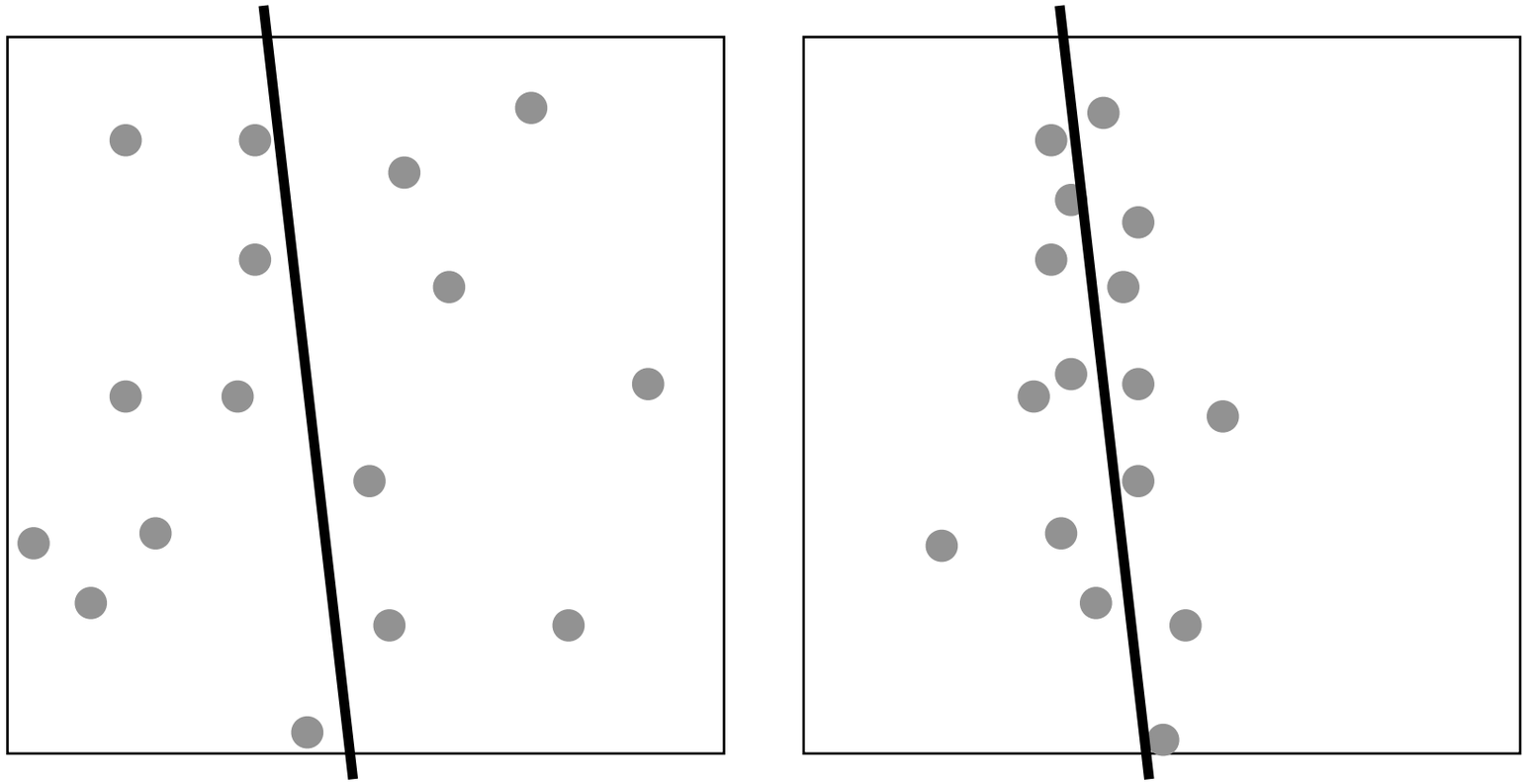
Prior α

Hypothesis generation and updating p_θ s_b

Item Memory n

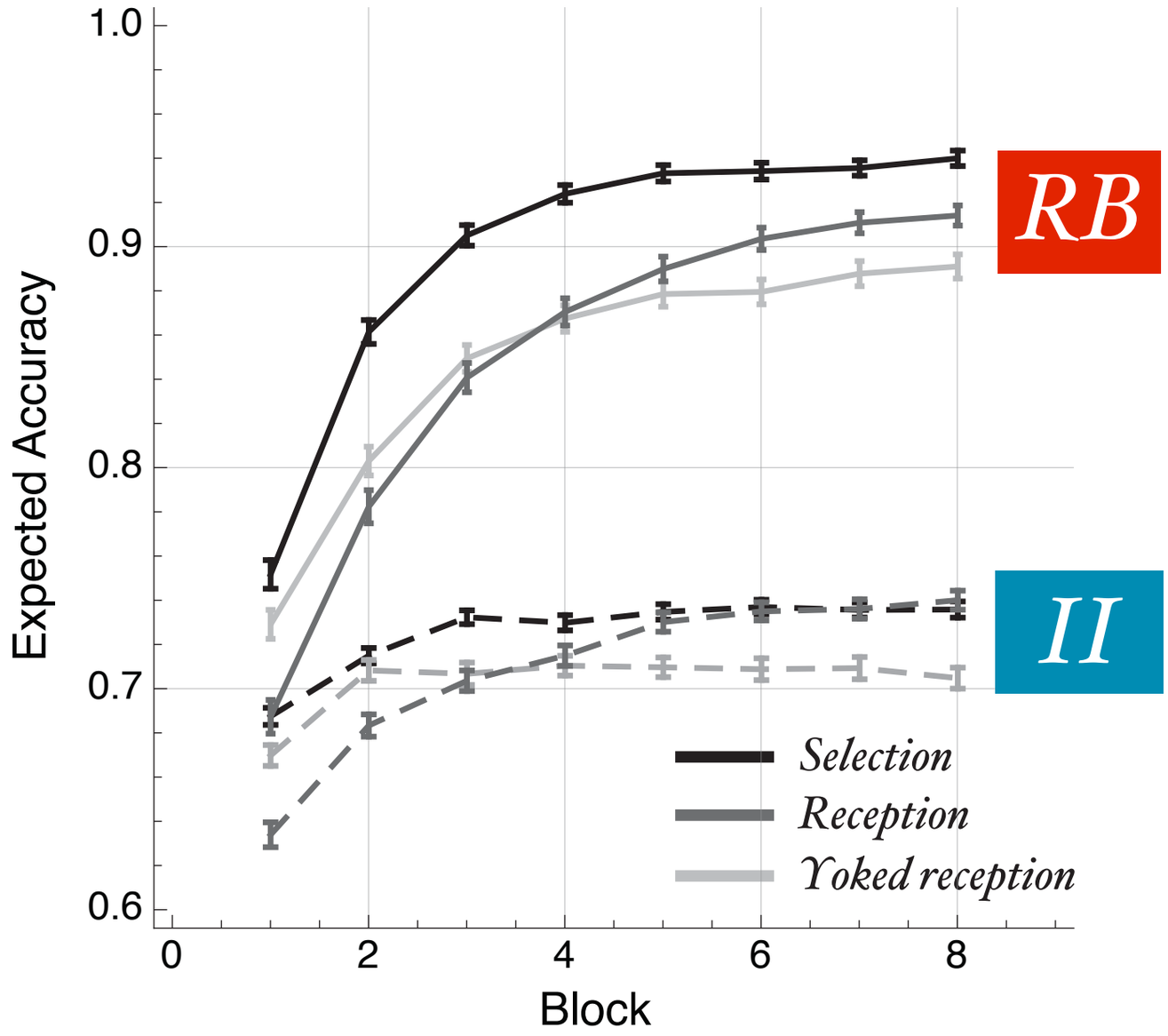
Hypothesis-dependent sampling bias S

S : Width of sampling distribution centered on current hypothesis (selection condition only)



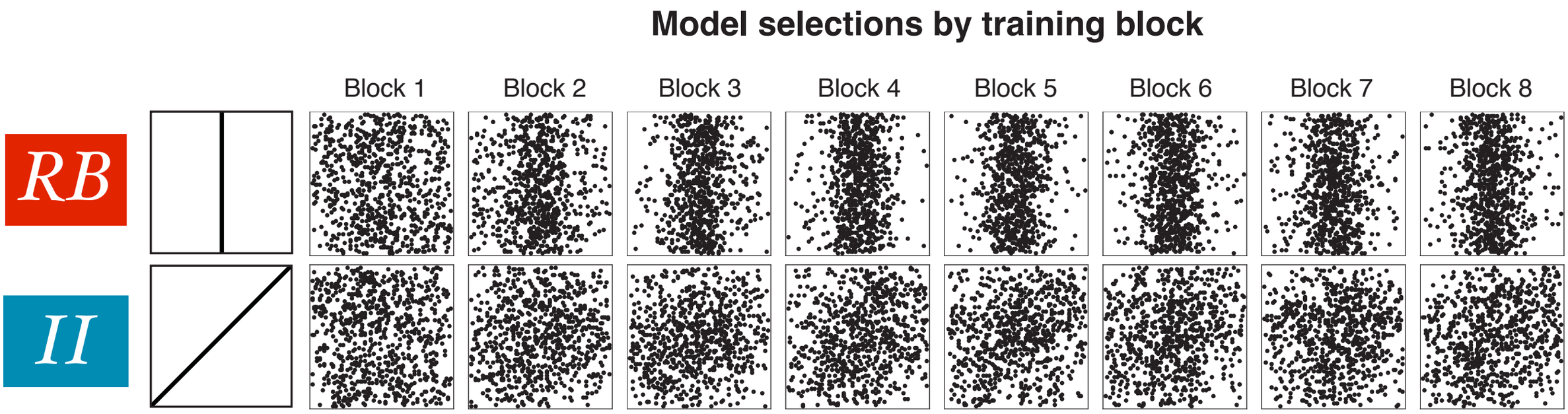
high *S* **low *S***

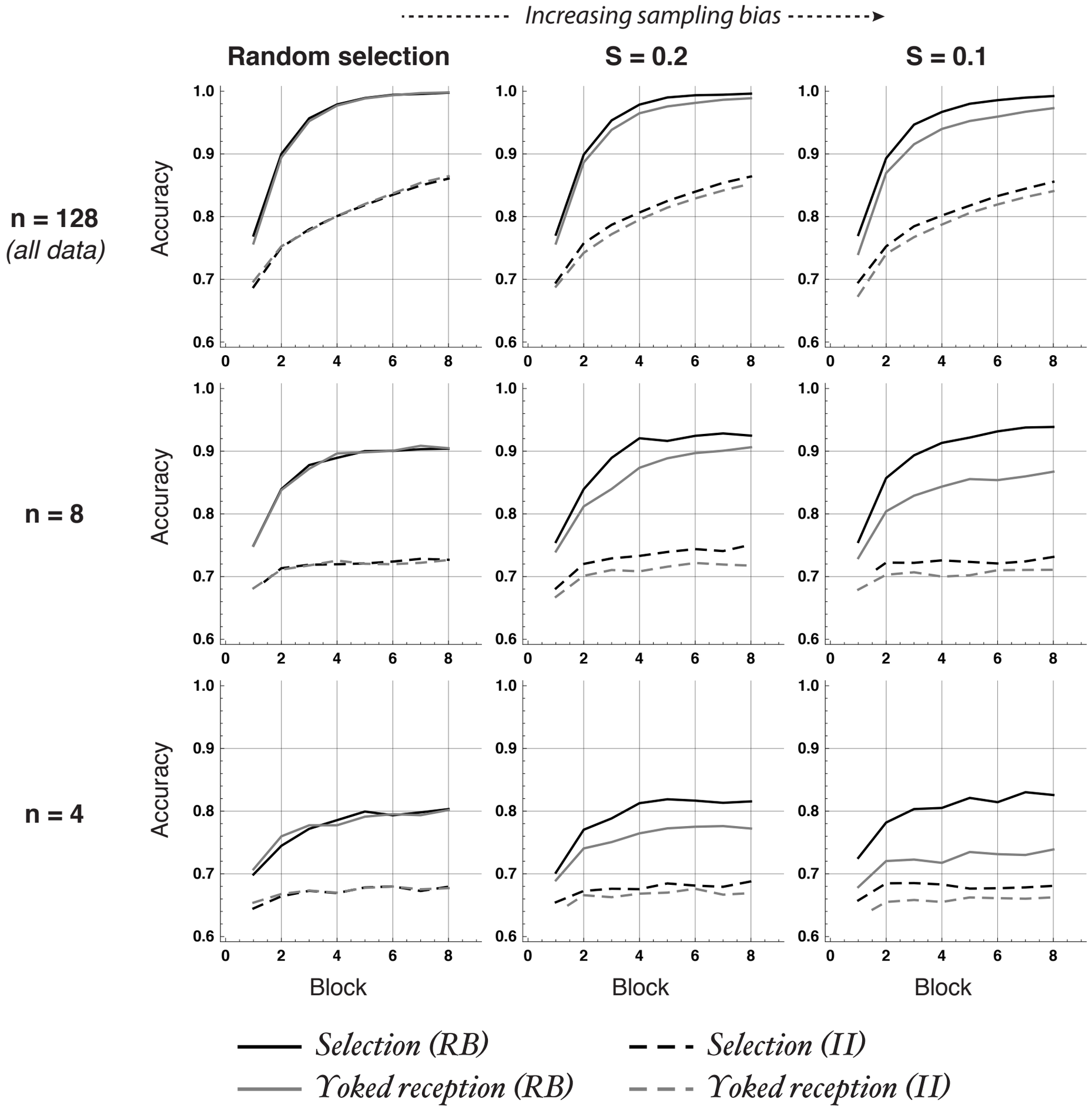
Model results



Symbol	Value	Parameter meaning
n	8	Number of observations
α	0.2	Prior weight
p_θ	0.3	Probability of modifying θ
s_b	0.15	Width of proposal distributions for b
S	0.1	Width of selection distribution

Model results




Increasing sampling bias
Random selection
S = 0.2
S = 0.1
n = 128
(all data)
n = 8
n = 4
Accuracy
Block
1.0
0.9
0.8
0.7
0.6
0
2
4
6
8
Selection (RB)
Yoked reception (RB)
Selection (II)
Yoked reception (II)

Study 1: Summary

- Selection leads to more efficient for RB task, but not II task, relative to typical reception condition
- Within the selection condition, performance is tied to the data generated by the participant, with items closer to the boundary associated with higher performance
- Despite learning from the same data, yoked learners perform worse than their selection partners in both tasks.
- A *hypothesis-dependent sampling bias* can account for the relative performance, without assuming any additional differences between conditions

The effects of self-directed learning

Data-driven: What is the *outcome,* in terms of the data experienced during learning?	**Decision-driven:** What processes are related to the *execution* of decisions?
Collect more informative data than is typically experienced	Recruitment of additional processes (e.g., prediction, explanation, etc.)
Expose data that is unavailable from passive observation	Improved attentional coordination with flow of experience
Generate data that tests current hypothesis	Inherent rewards or engagement associated with free choice and exploration

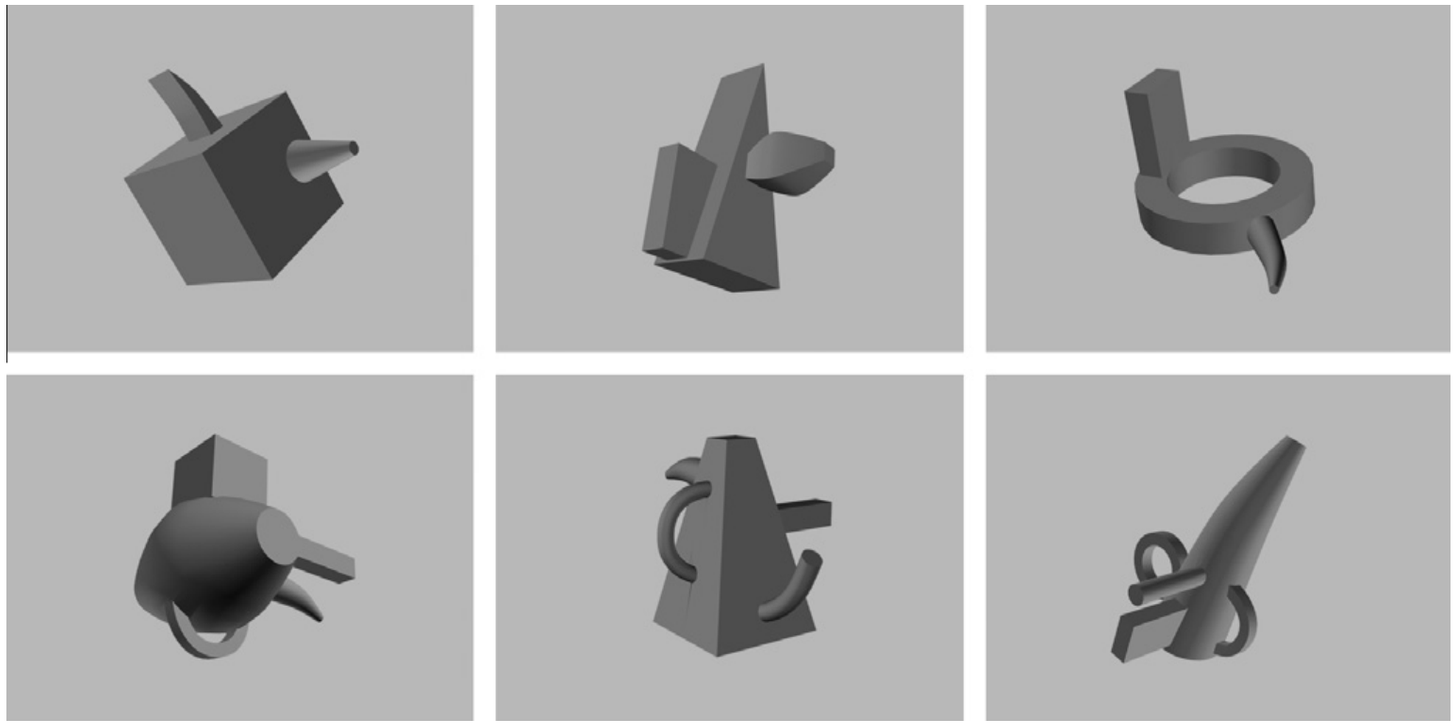
The effects of self-directed learning

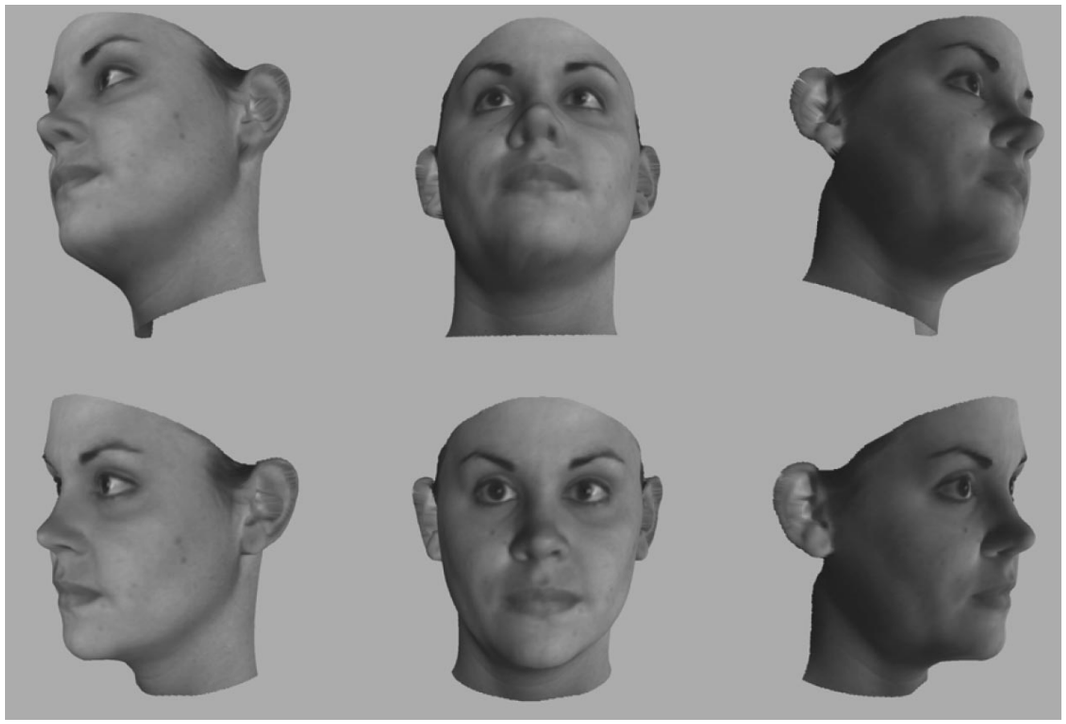
Data-driven: What is the *outcome,* in terms of the data experienced during learning?	**Decision-driven:** What processes are related to the *execution* of decisions?
Collect more informative data than is typically experienced	Recruitment of additional processes (e.g., prediction, explanation, etc.)
Expose data that is unavailable from passive observation	Improved attentional coordination with flow of experience
Generate data that tests current hypothesis	Inherent rewards or engagement associated with free choice and exploration

Study 2: Active exploration and episodic memory

Markant, D., Dubrow, S., Davachi, L., Gureckis, T. (submitted). Deconstructing the effect of self-directed study on episodic memory.

Self-directed study and episodic memory



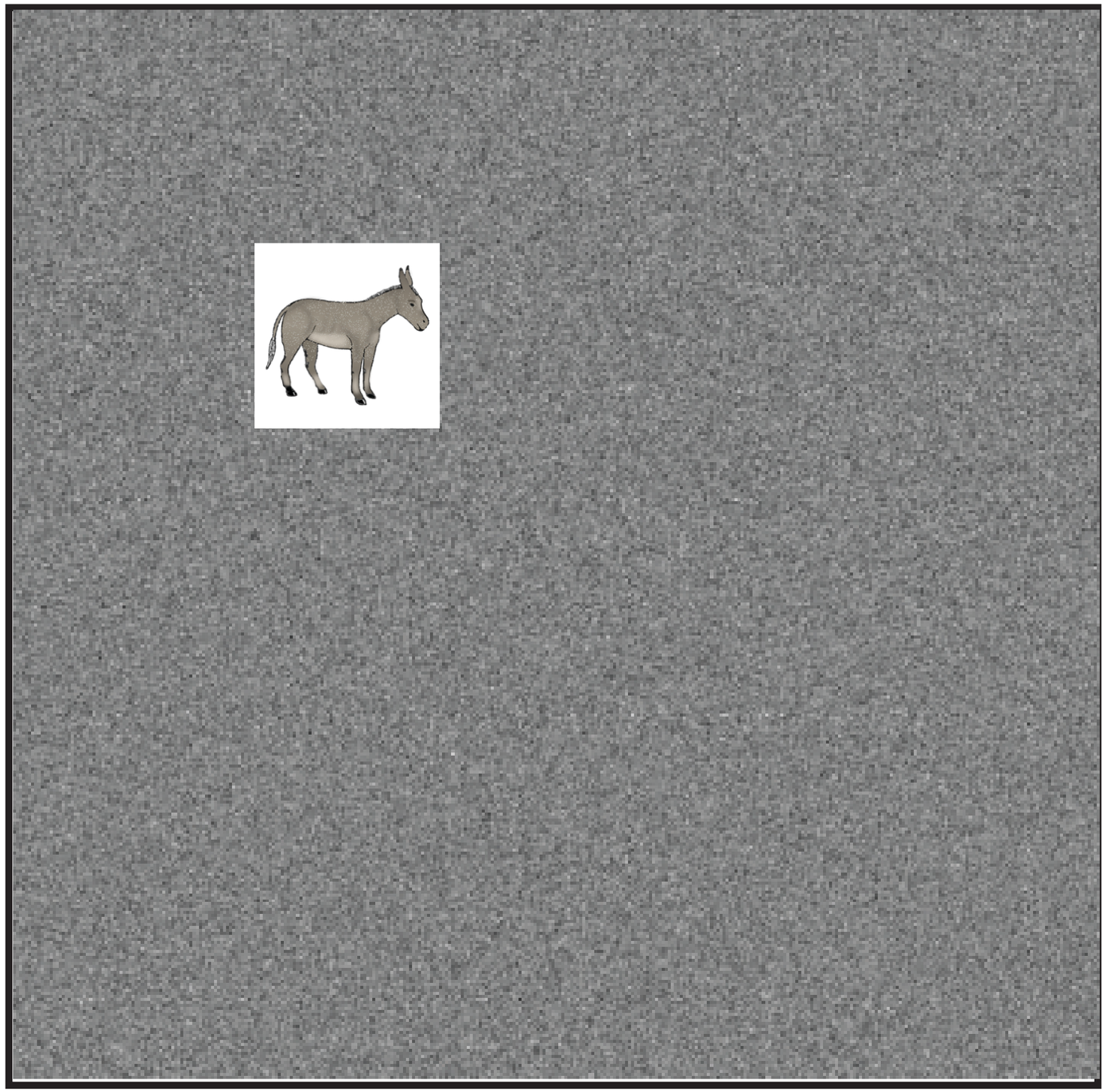


Harman, K., Humphrey, G., and Goodale, M. (1999), Current Biology

Liu., C.H., Ward, J., and Markall, H. (2007), JEP:HPP

Meijer, F. and Van der Lubbe, R. H. J. (2011), Vision Research

Task



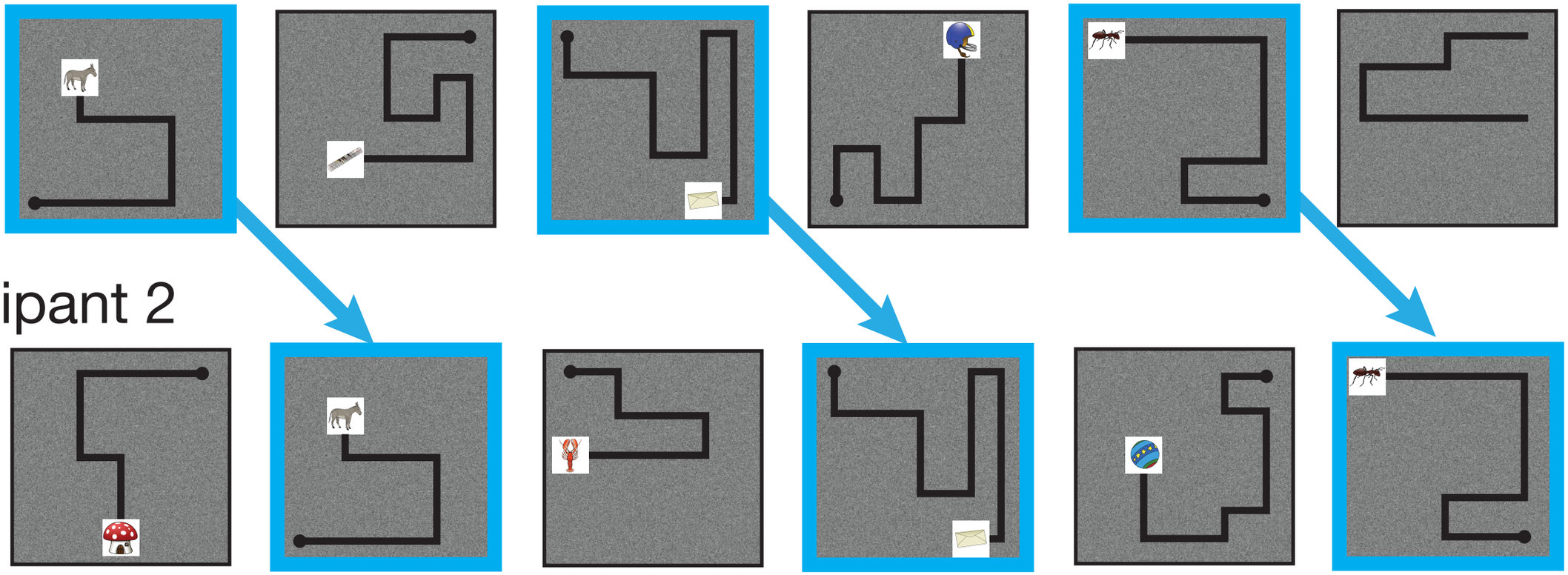
Voss, J. et al. (2011). Hippocampal brain-network coordination during exploratory behavior enhances learning. Nature Neuroscience.

Task

Voss, J. et al. (2011). Hippocampal brain-network coordination during exploratory behavior enhances learning. Nature Neuroscience.

Yoked Design

Participant 1

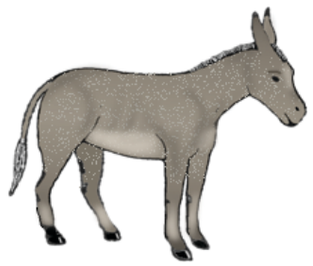


Participant 2

6 study rounds, 1 minute each
20 second rest between rounds
2 minute break before final test

Memory Test

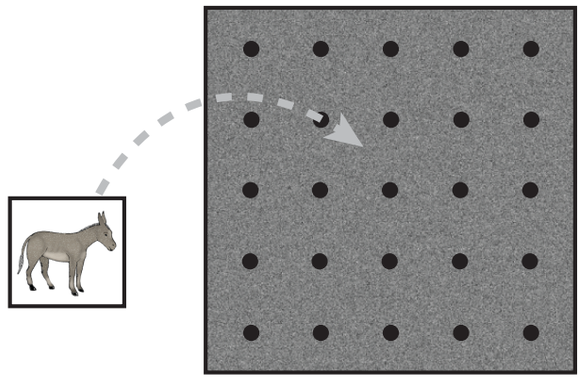
RECOGNITION



OLD or NEW?

"OLD"

SPATIAL RECALL

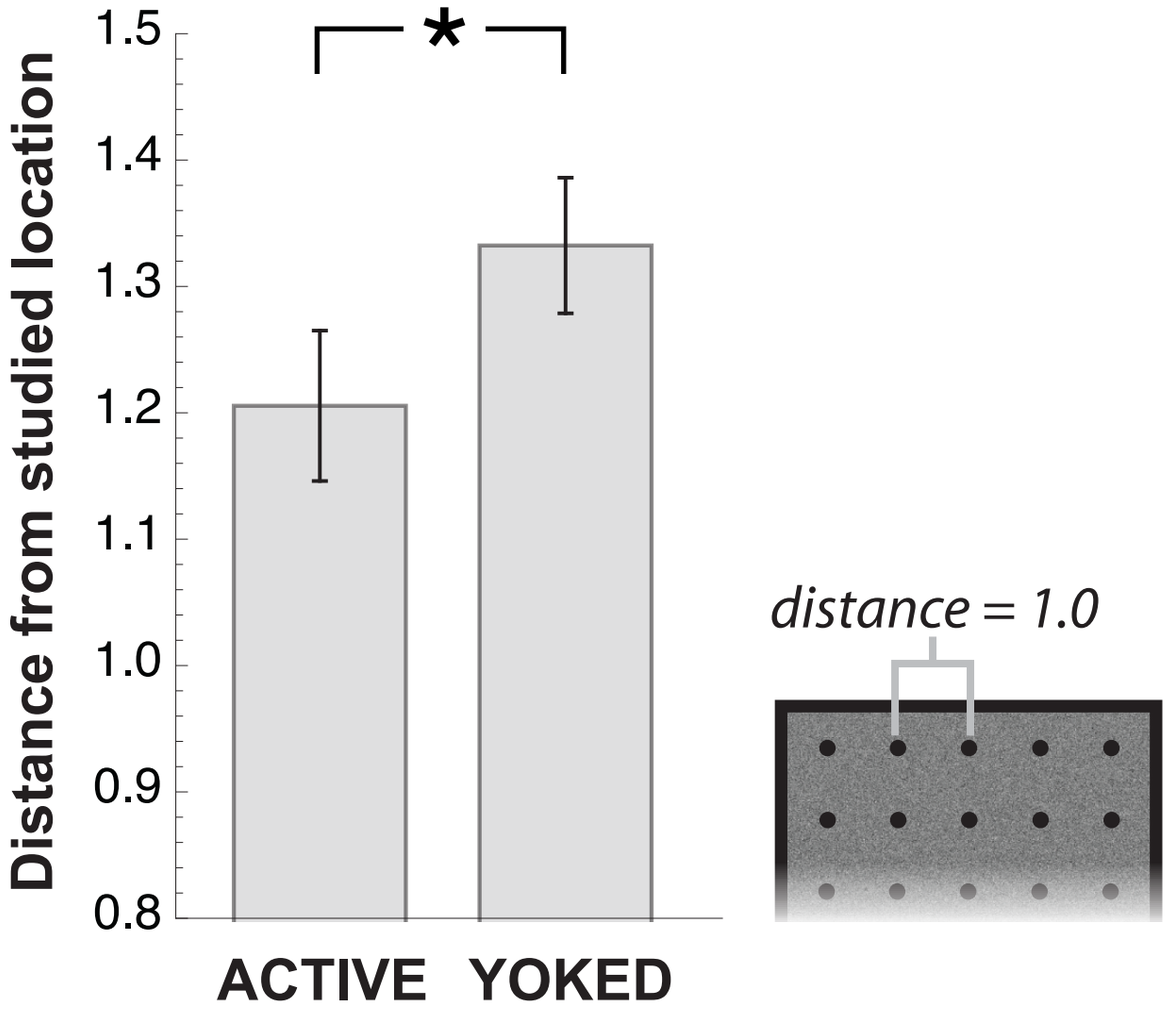


Where did it appear during study?

300 items tested for recognition, 150 old and 150 new
Spatial recall test was contingent on responding OLD

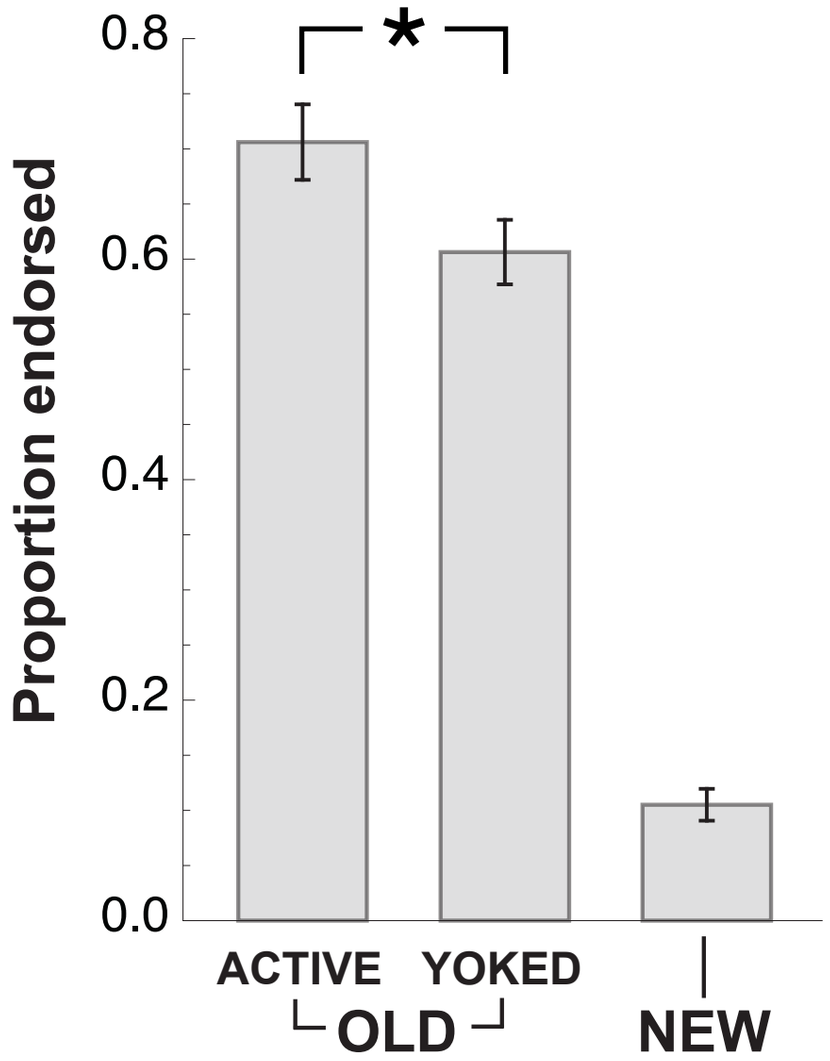
Experiment 1: Replication

Spatial recall



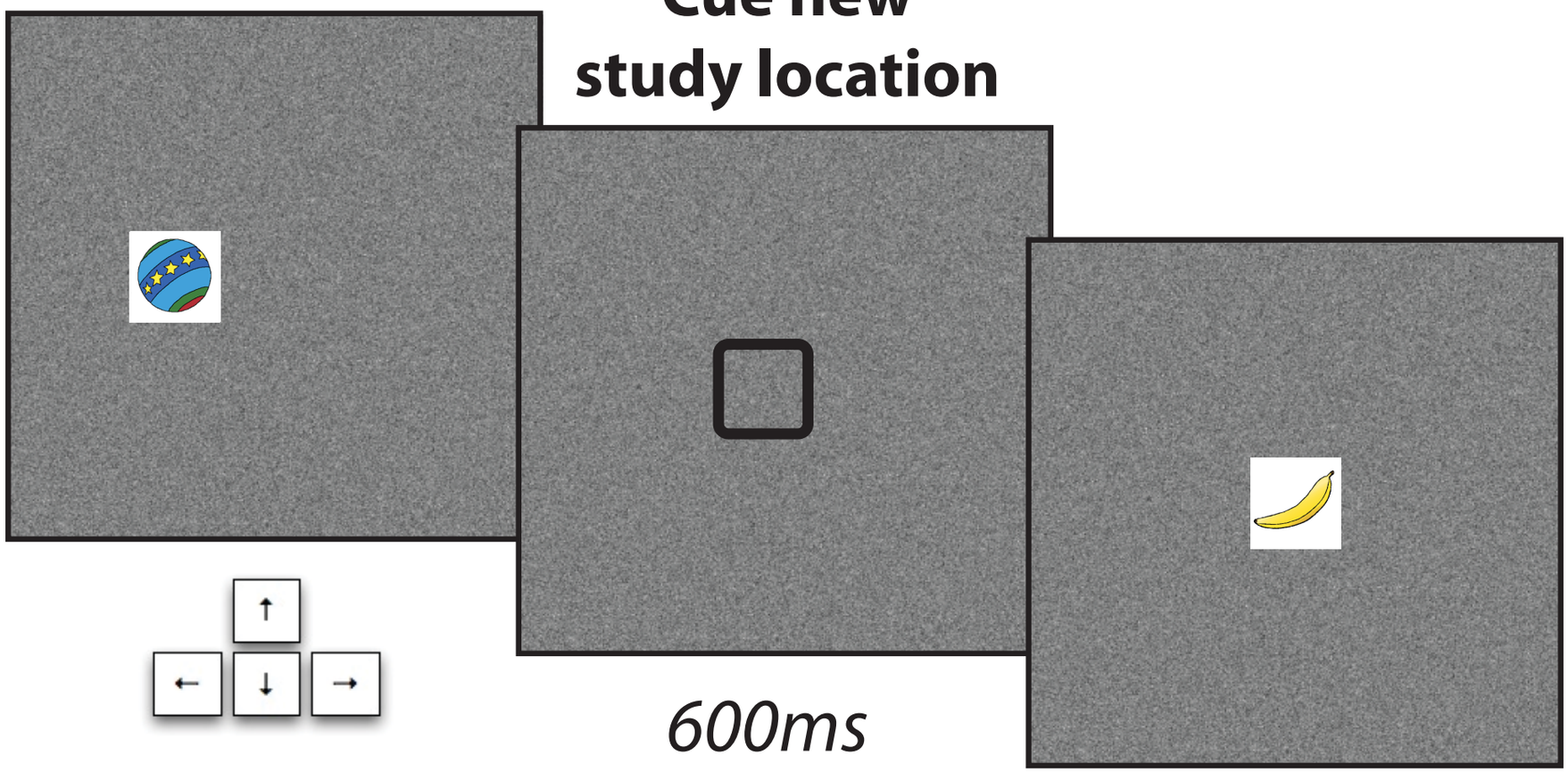
Mean difference = -.13
p = .01

Recognition



N = 30
Mean difference = .10
p < .001

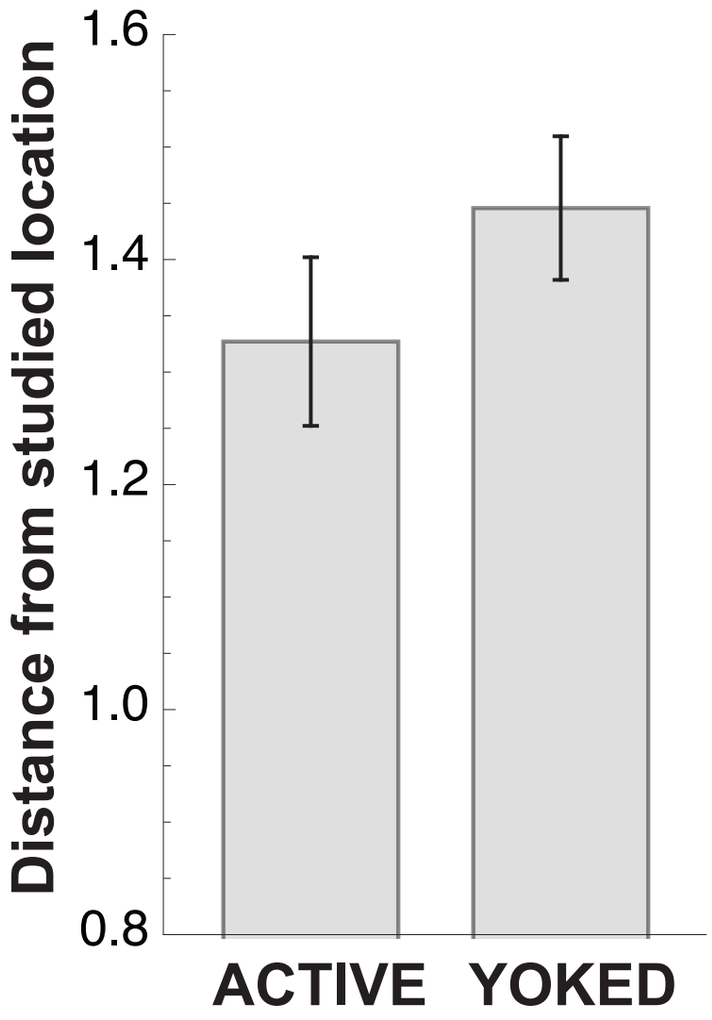
Experiment 2: Attentional cueing



	Exp 1	Exp 2	Exp 3	Exp 4
Control selection of next item	★	★		
Control item duration	★	★		
Cue next location (all blocks)		★		

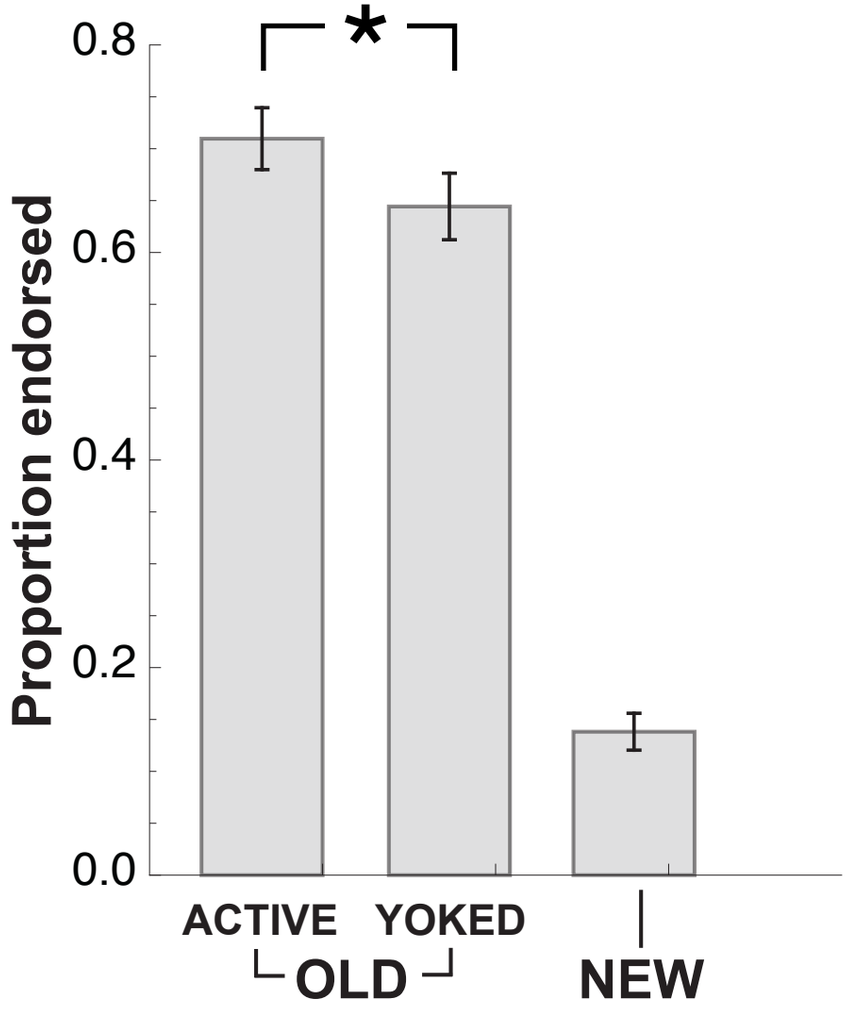
Experiment 2: Results

Spatial recall



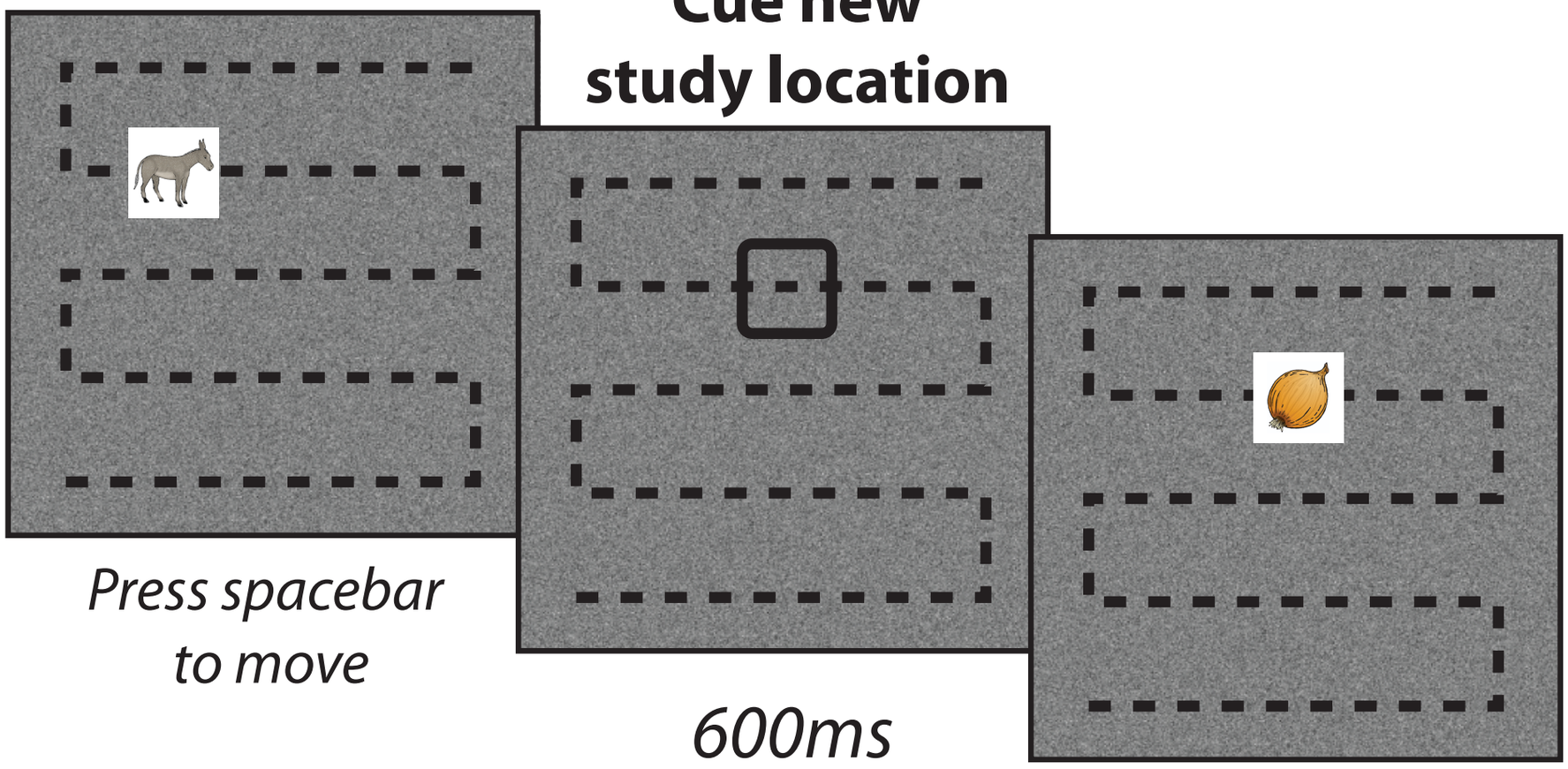
N = 30
Mean difference = -.01
p = .9

Recognition



N = 30
Mean difference = .07
p = .01

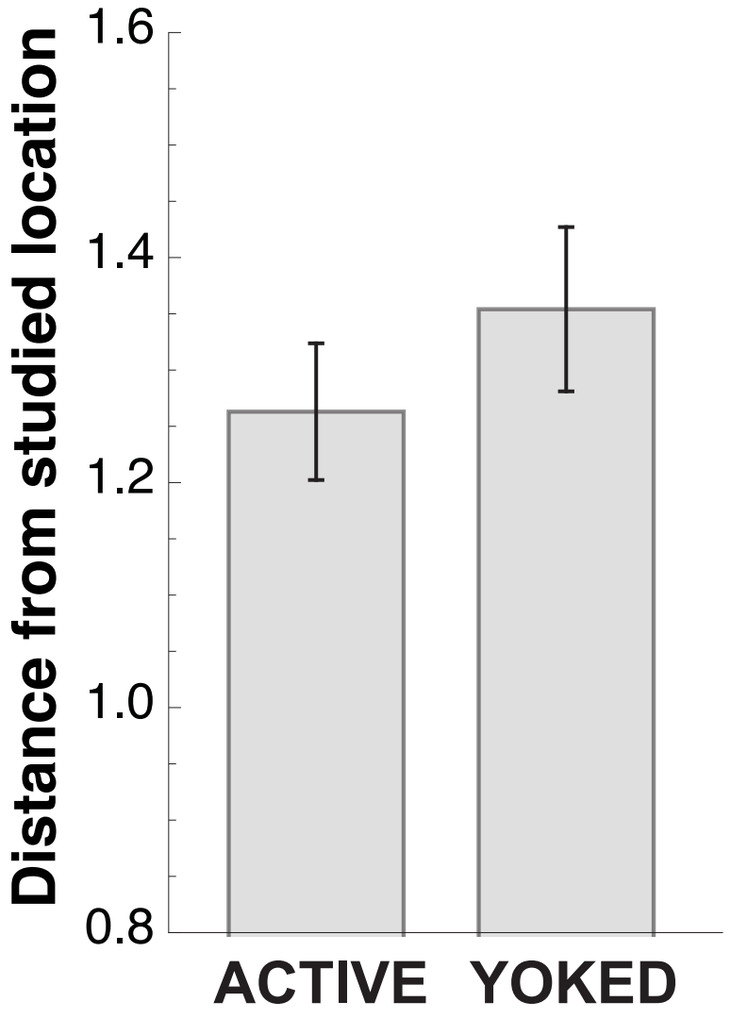
Experiment 3: Follow a fixed path



	Exp 1	Exp 2	Exp 3	Exp 4
Control selection of next item	★	★		
Control item duration	★	★	★	
Cue next location (all blocks)		★	★	

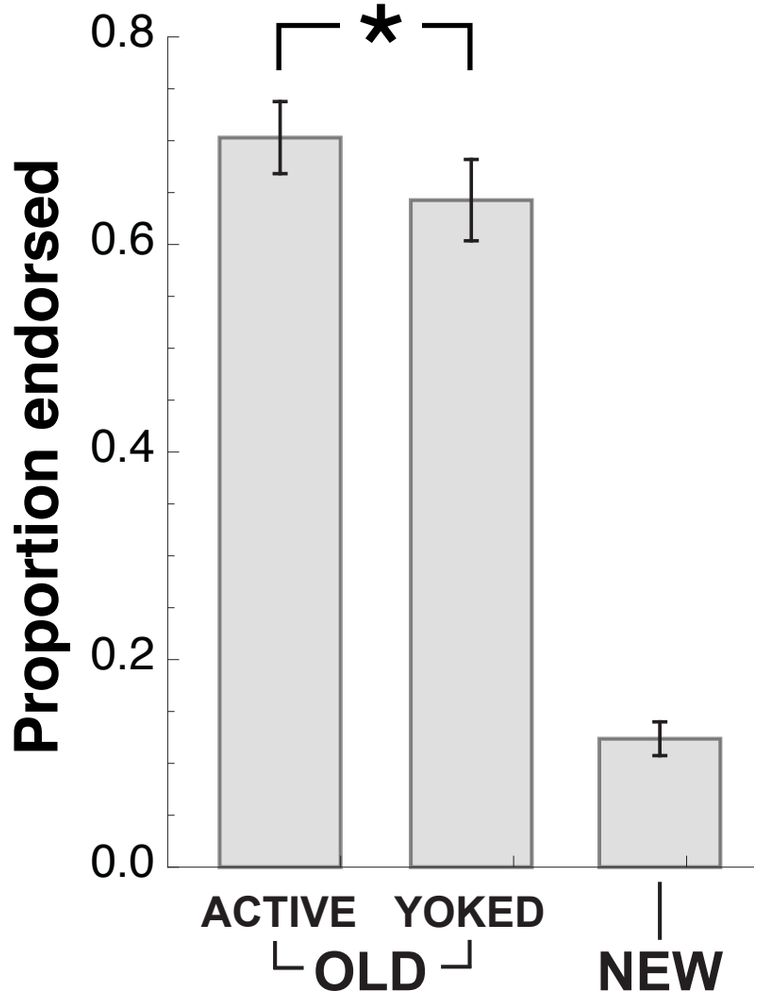
Experiment 3: Results

Spatial recall



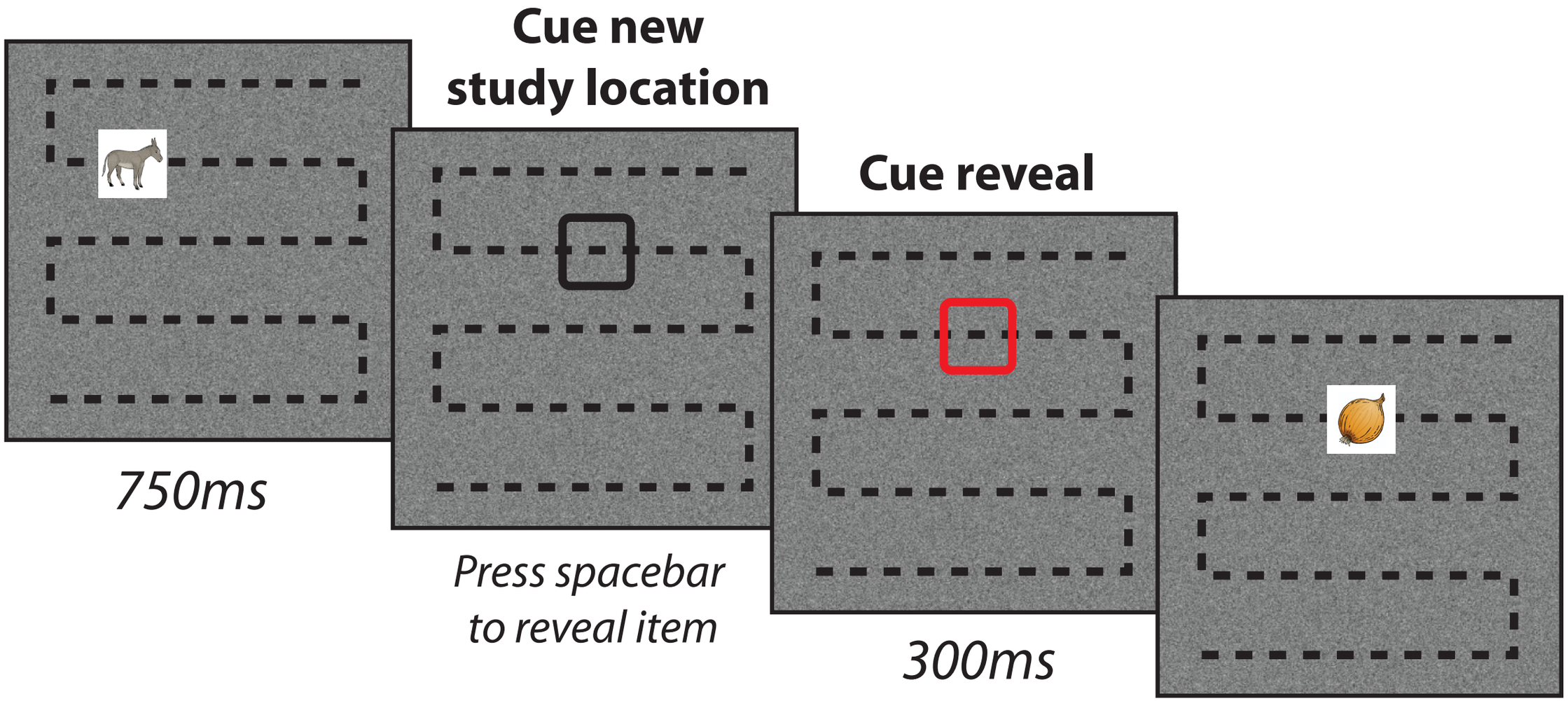
N = 32
Mean difference = -.09
p = .09

Recognition



N = 32
Mean difference = .06
p = .01

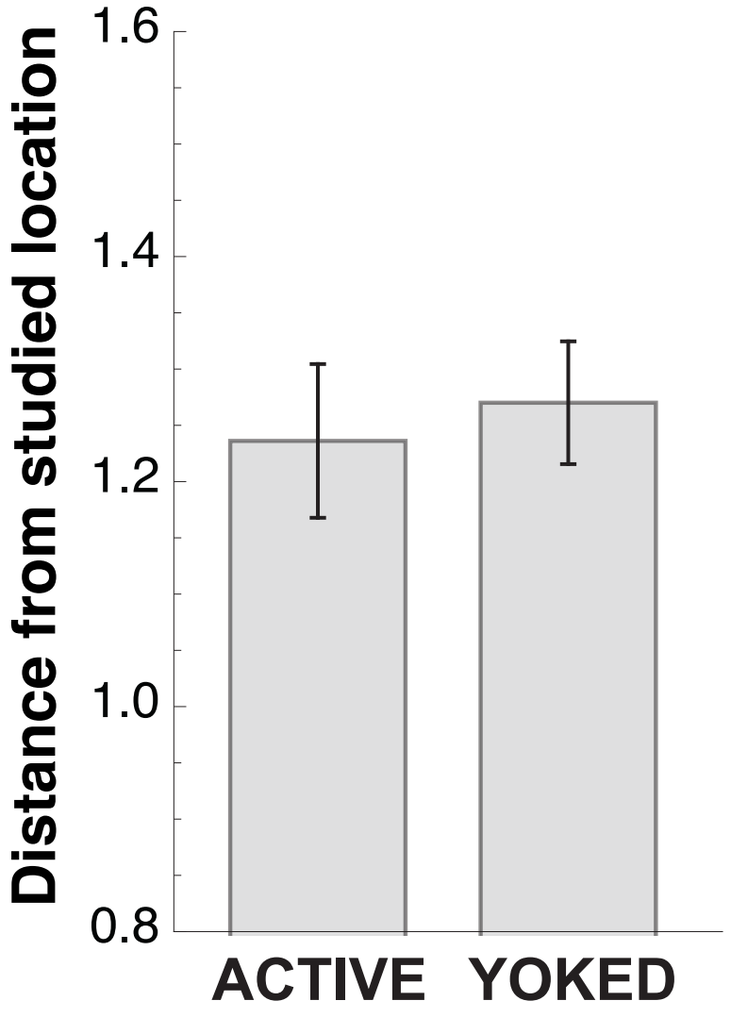
Experiment 4: Press to reveal next item



	Exp 1	Exp 2	Exp 3	Exp 4
Control selection of next item	★	★		
Control item duration	★	★	★	
Cue next location (all blocks)		★	★	★
Control onset of next item				★

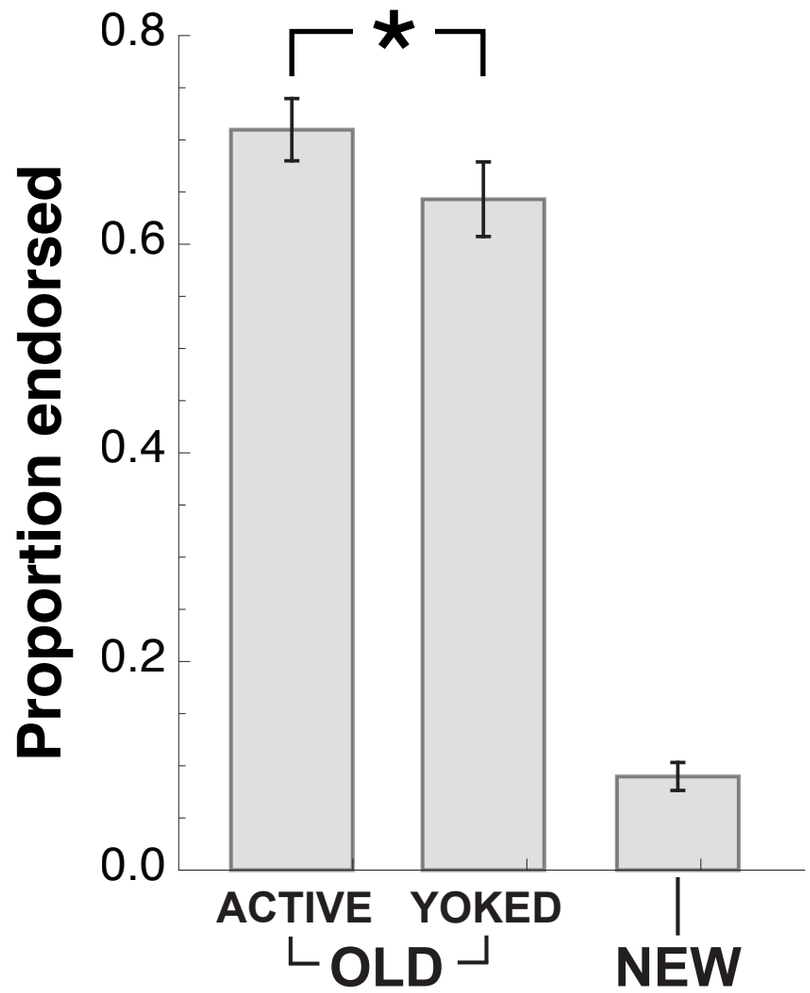
Experiment 4: Results

Spatial recall



N = 30
Mean difference = -.03
p = .52

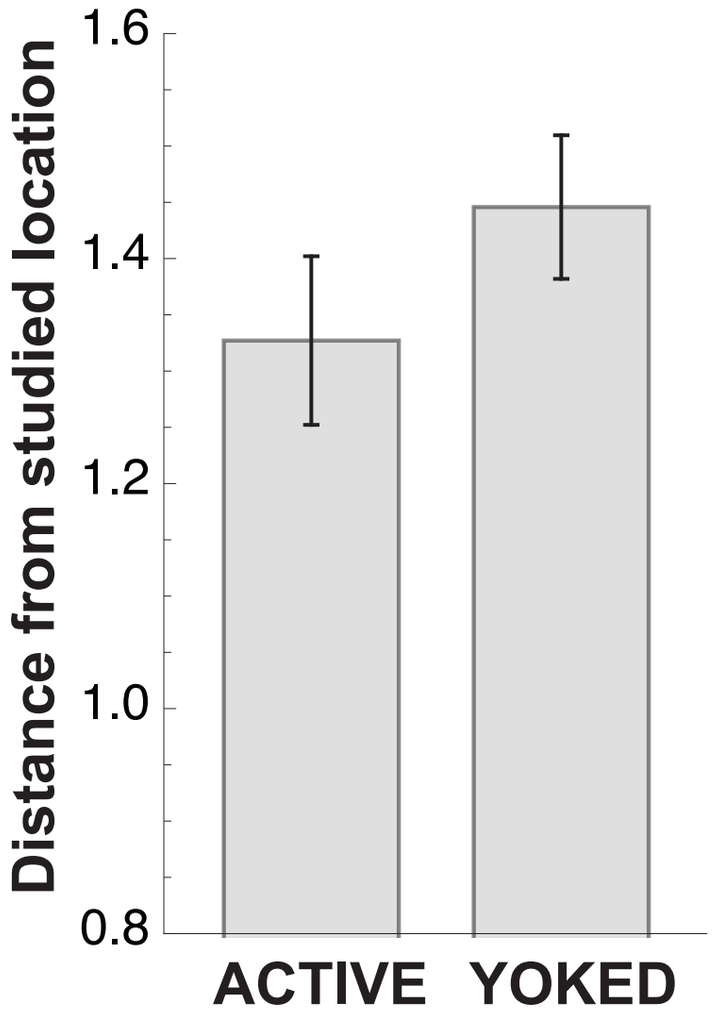
Recognition



N = 30
Mean difference = .07
p = .01

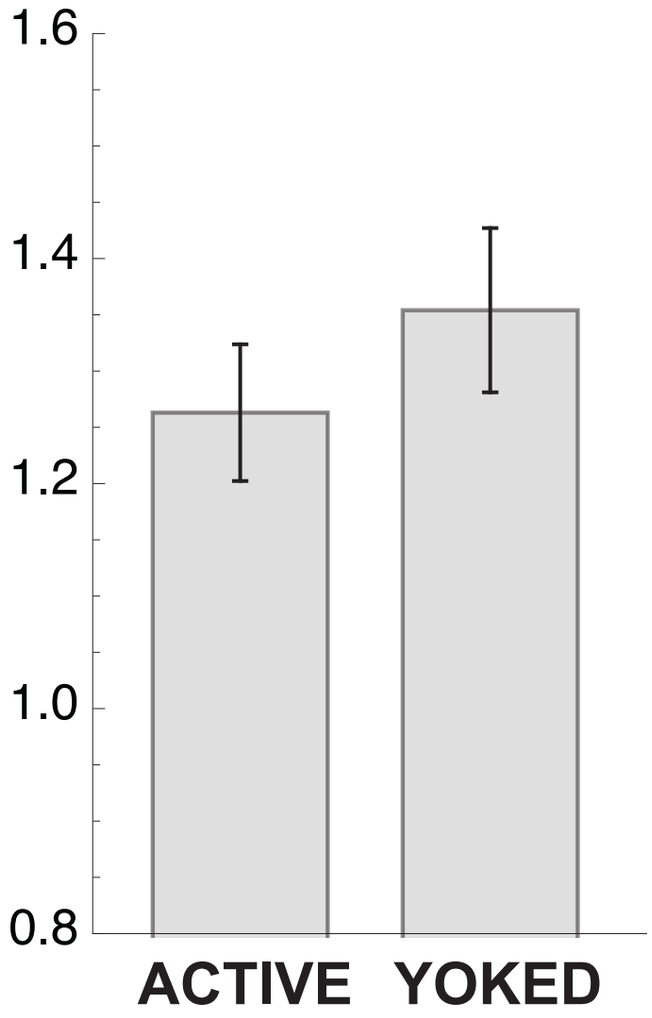
Results: Spatial recall

Exp 2: Cueing



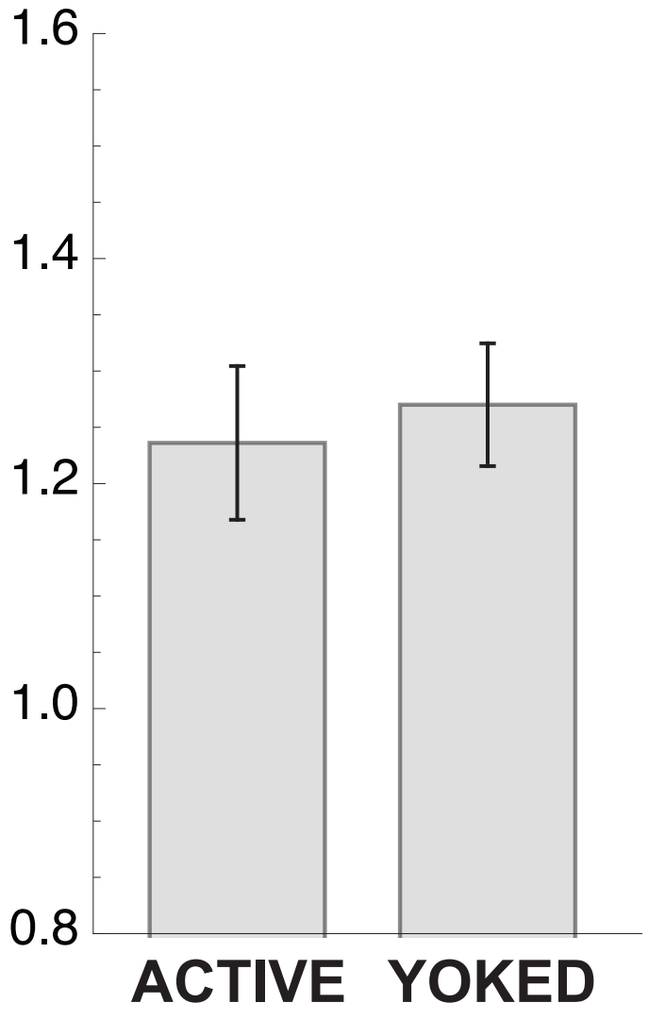
N = 30
Mean difference = -.01
p = .9

Exp 3: Follow a fixed path



N = 32
Mean difference = -.09
p = .09

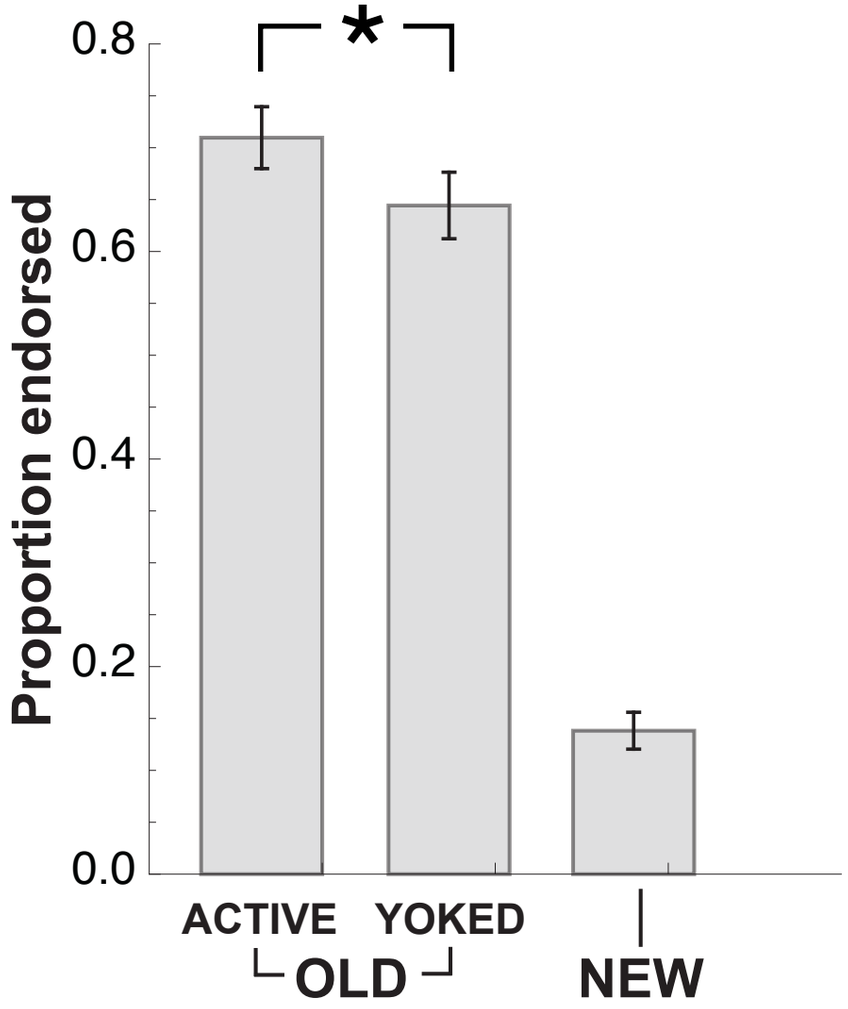
Exp 4: Press to reveal



N = 30
Mean difference = -.03
p = .52

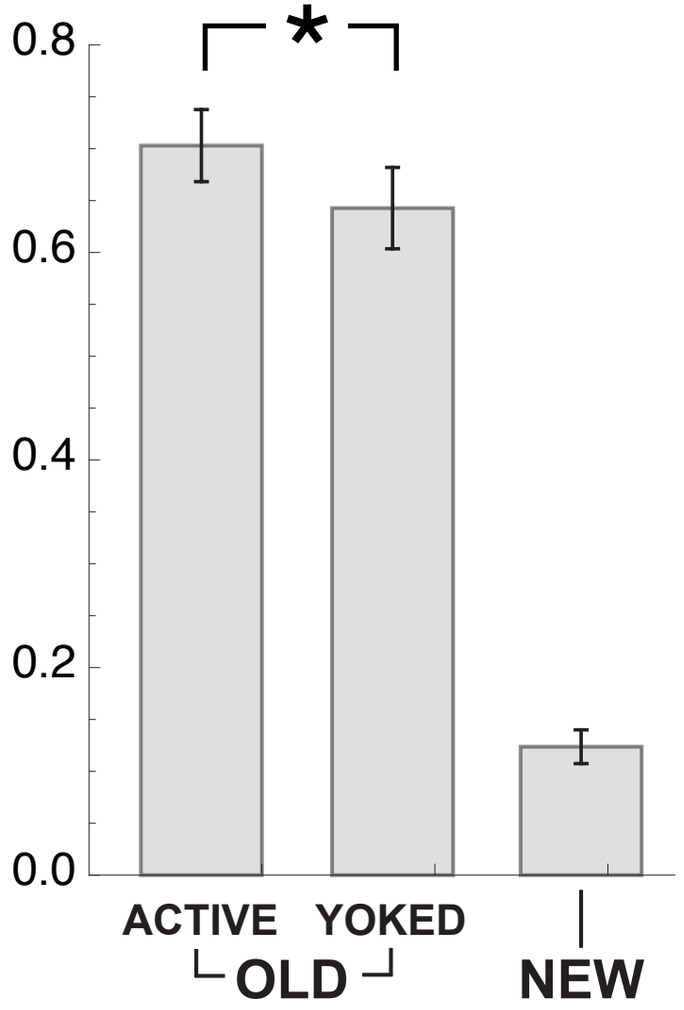
Results: Recognition

Exp 2: Cueing



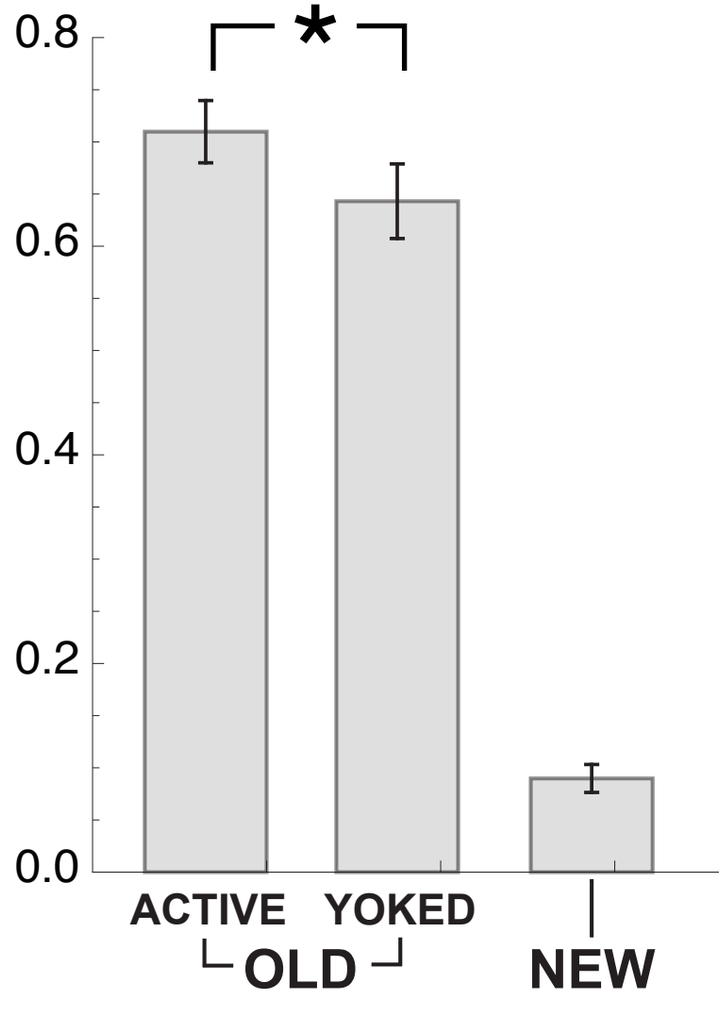
N = 30
Mean difference = .07
p = .01

Exp 3: Follow a fixed path



N = 32
Mean difference = .06
p = .01

Exp 4: Press to reveal



N = 30
Mean difference = .07
p = .01

Study 2: Summary

- Inconsistent evidence for an advantage in spatial recall; seems to depend on ability to coordinate attention, rather than self-directed exploration
- “Minimal” degree of control over the timing of study episodes leads to a consistent benefit in recognition memory
    - Coordinating the timing of new study episodes with attentional or motivational state
    - Intrinsic reward involved in choice-dependent study

Conclusions

Data-driven effects: What is the *outcome,* in terms of the data experienced during learning?	**Decision-driven effects:** What processes are related to the *execution* of decisions?
Collect more informative data than is typically experienced	Recruitment of additional processes (e.g., prediction, explanation, etc.)
Expose data that is unavailable from passive observation	Improved attentional coordination with flow of experience
Generate data that tests current hypothesis	Inherent rewards or engagement associated with free choice and exploration

THANKS!