Uncertainty alters the balance between incremental learning and episodic memory

Jonathan Nicholas[1], Nathaniel D. Daw[2], and Daphna Shohamy[1]

[1]Department of Psychology and Zuckerman Mind Brain Behavior Institute, Columbia University
[2]Department of Psychology and Princeton Neuroscience Institute, Princeton University
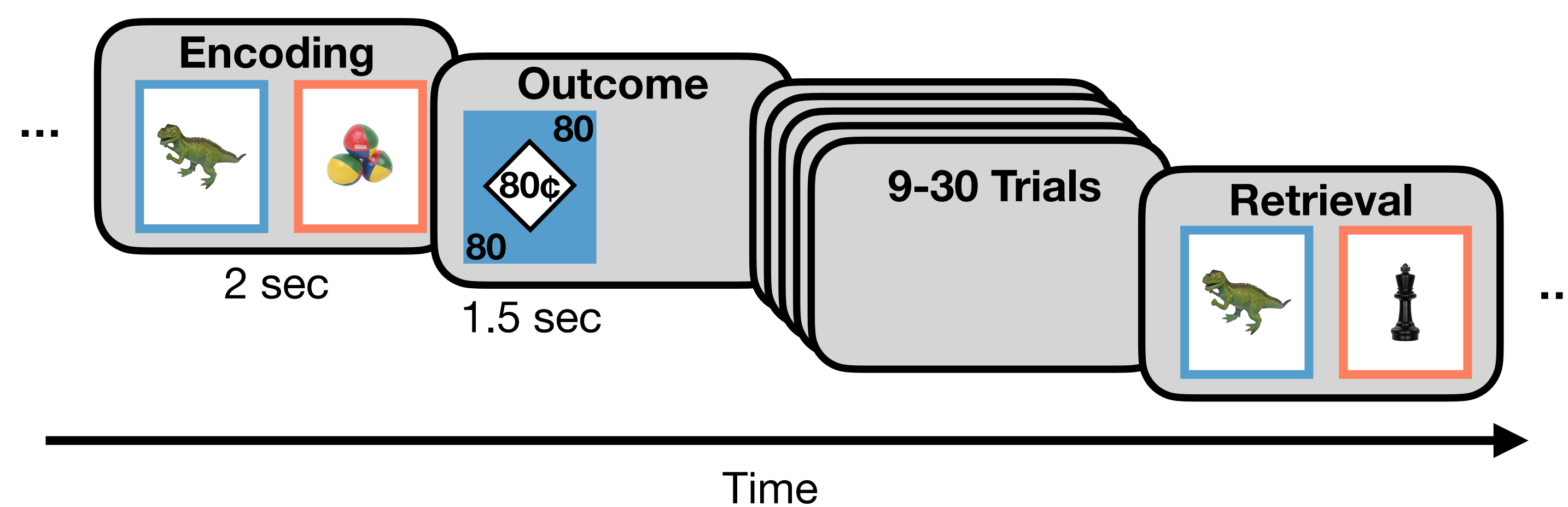
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Background

- Most work on decision making has focused on incremental learning from trial-and-error. Yet, some decisions may require episodic memory.

- Episodic memory is useful for choice when there is simply not enough ... accurate and reliable incremental estimates.

- Prediction: Ep... ...ruited for decision making when estimates about valu...

Encoding
New   New

9-30 Trials

Primary Question | Does uncerta... ... ...ate the extent to which decisions are guided by in... ...arning or episodic memory?

Experiment

Encoding — 2 sec
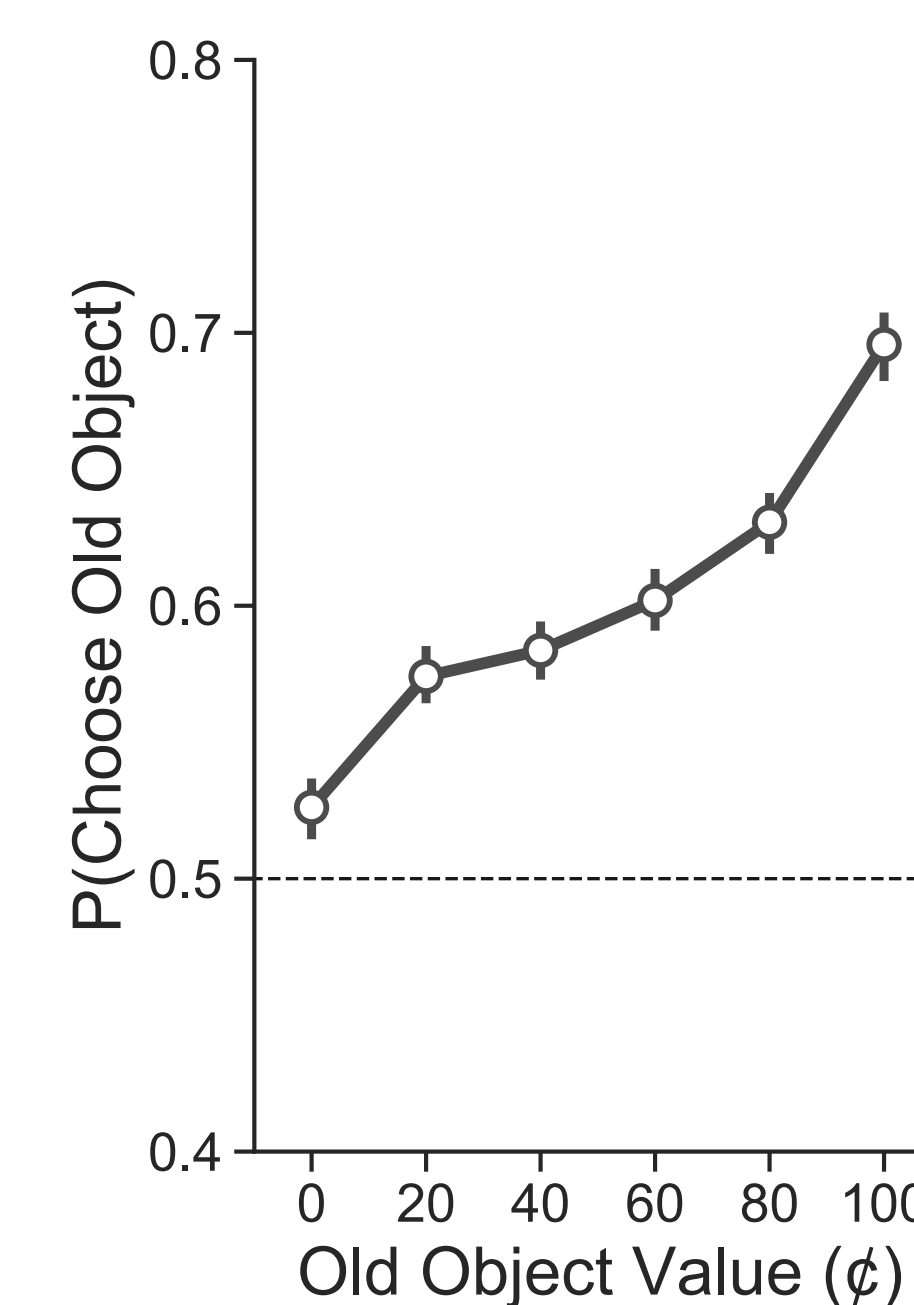**Outcome** — 80 / 80¢ / 80 — 1.5 sec
9-30 Trials
Retrieval

Time

- **254 subjects recruited from mTurk completed a two-armed bandit task.**

- **Choices were between two decks that reversed in expected value periodically. Outcomes were between $0 - $1 in increments of twenty cents.**

- **Decks also featured cards with trial-unique objects that could repeat once after 9-30 trials and were worth the same amount.**

Low Volatility | High Volatility
True Deck Value vs Trial Number (50, 100, 150, 200, 250, 300)
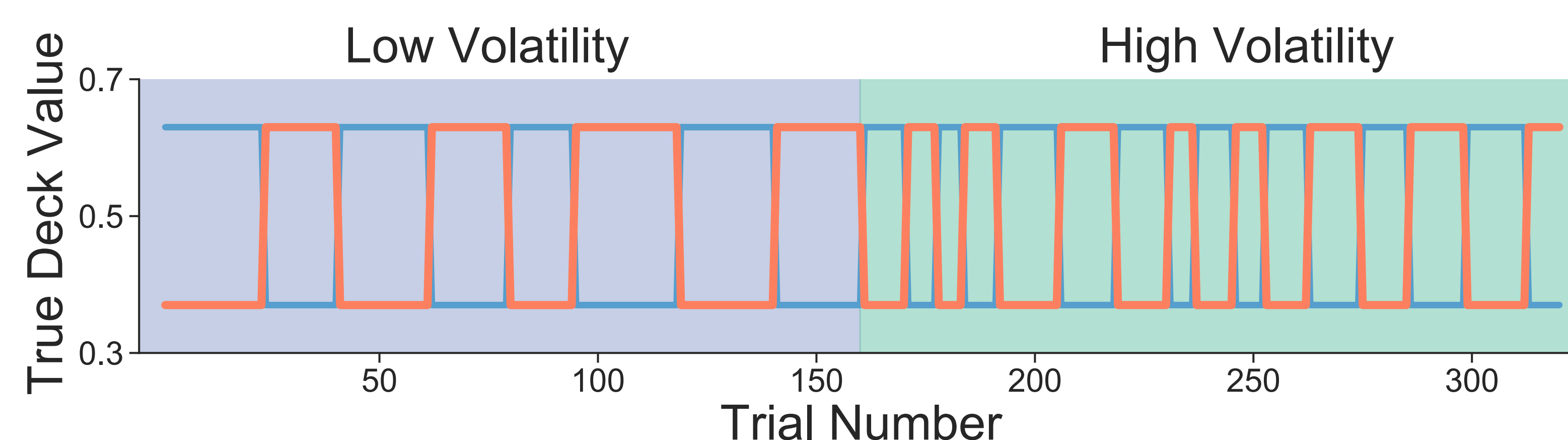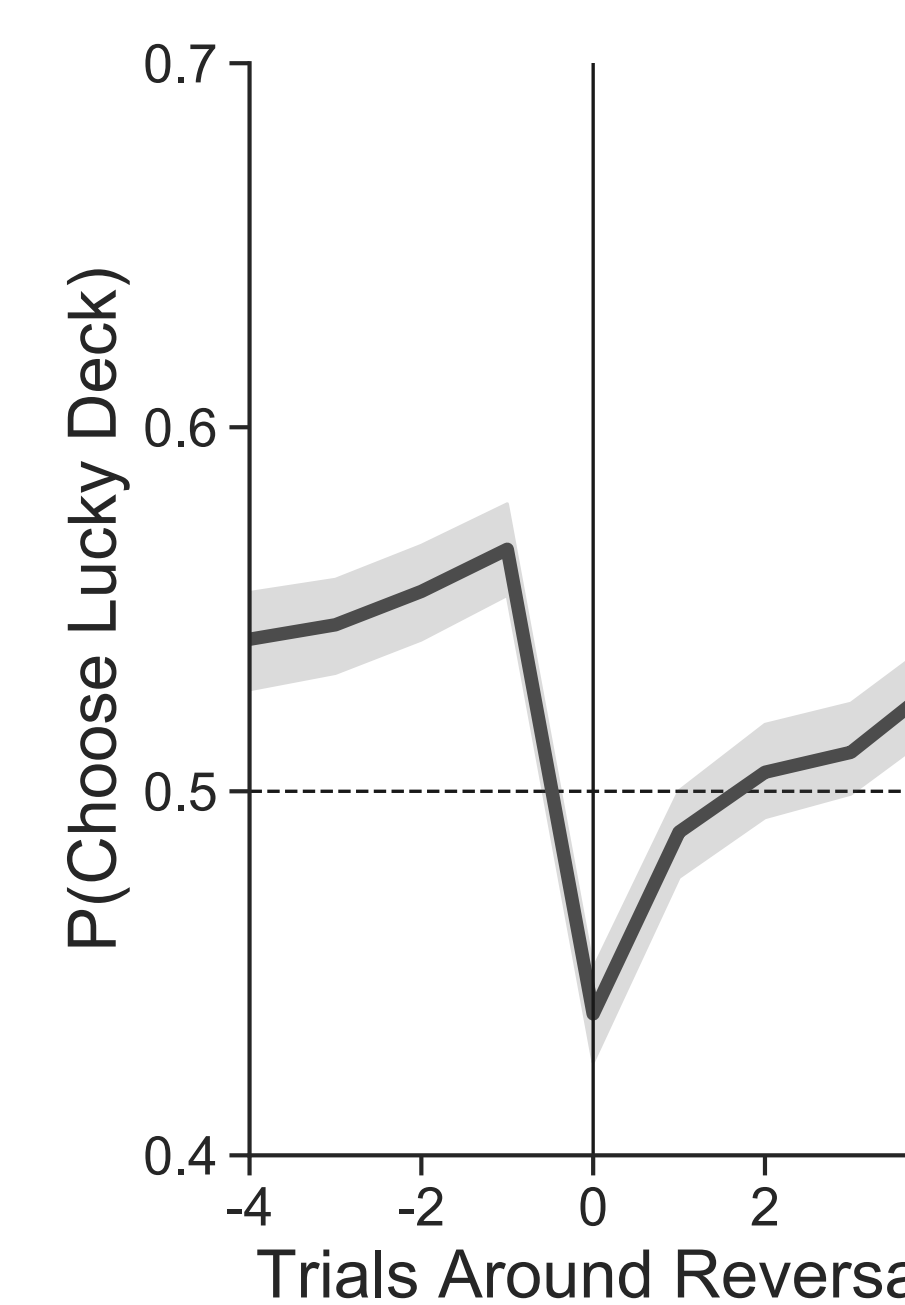
- **Subjects made choices across two environments with high and low volatility.**

- **This allowed us to test for effects of uncertainty both across environments and after reversals in deck value.**

Subjects use both sources of value

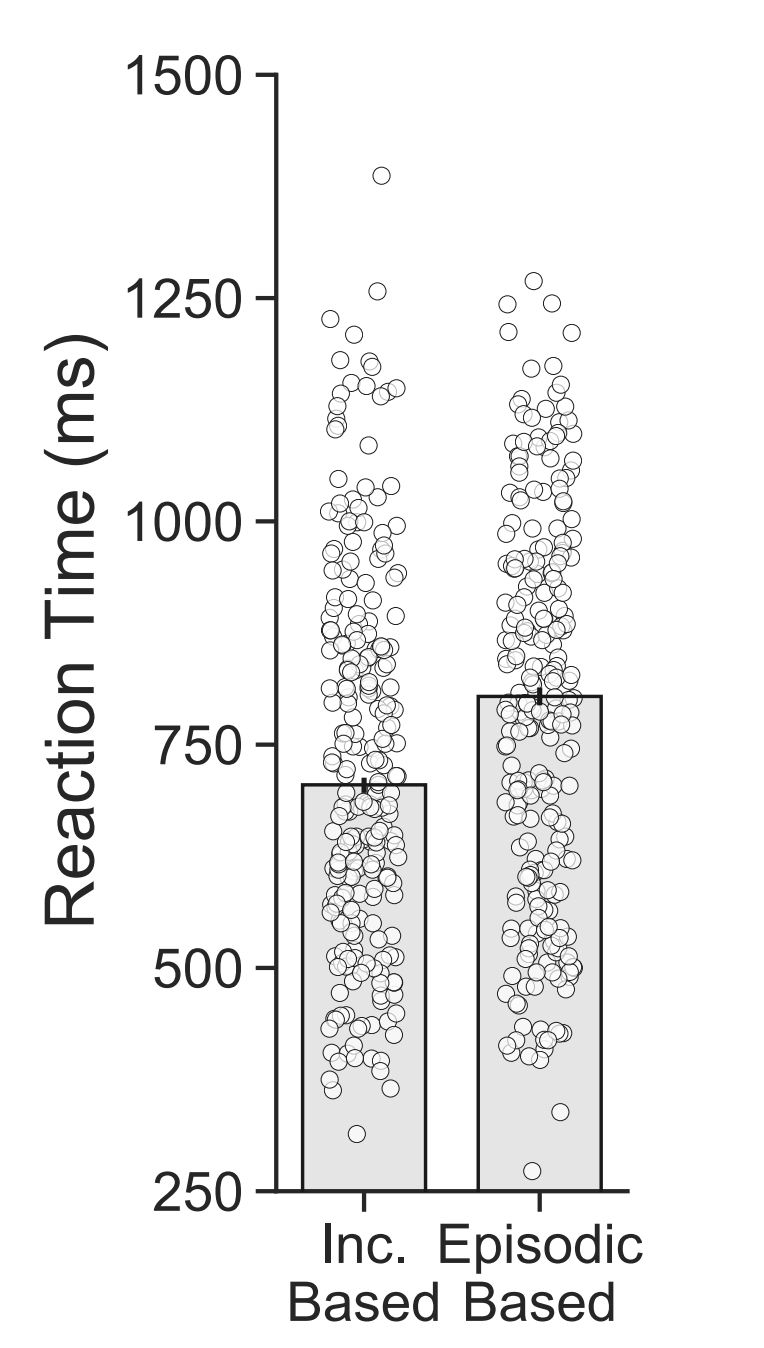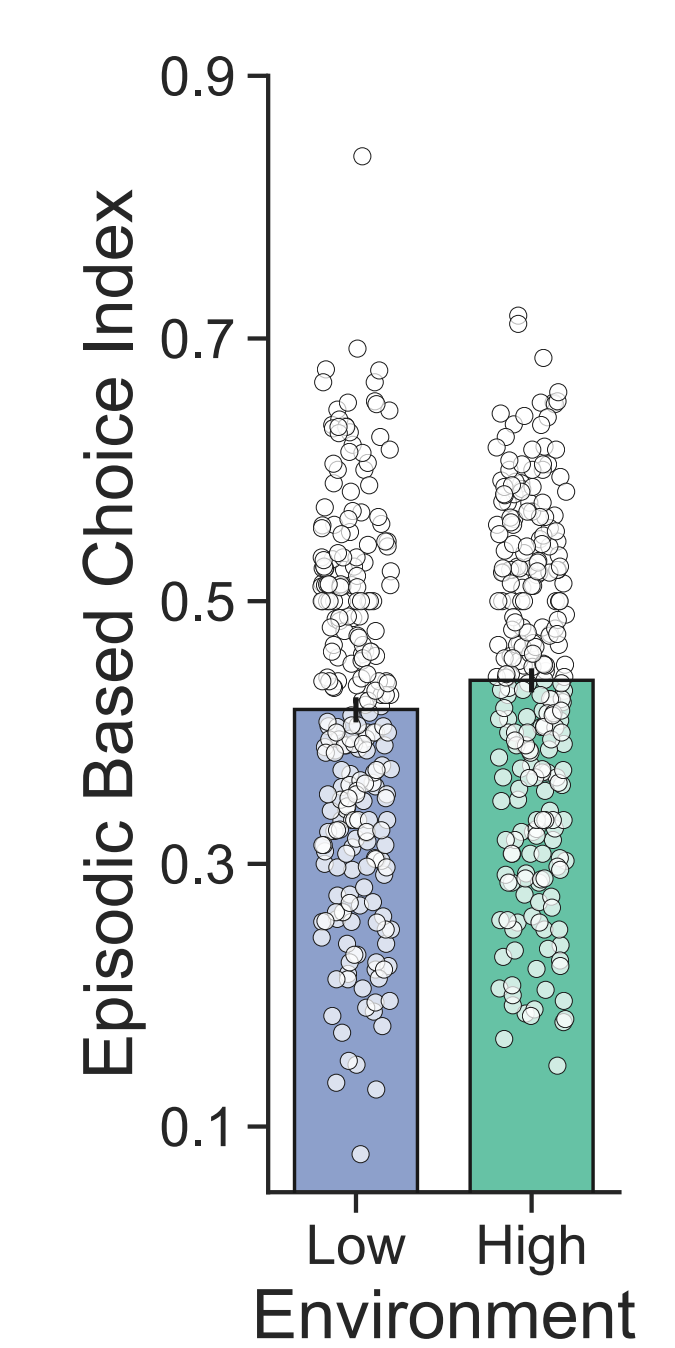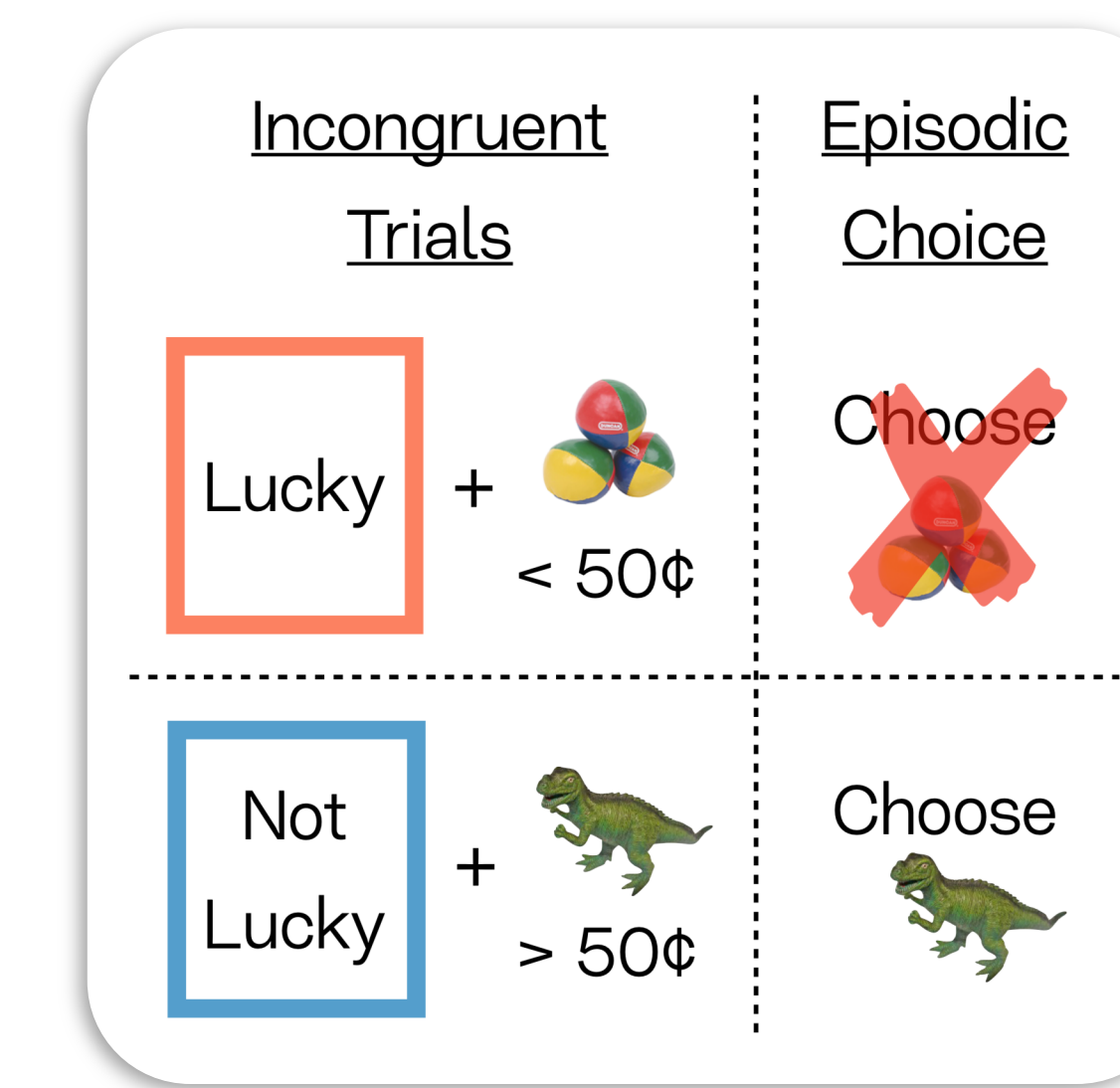**Choices are sensitive to old object value**

Retrieval
Old   New

P(Choose Old Object) vs Old Object Value (¢): 0, 20, 40, 60, 80, 100

...and to reversals in deck value.

P(Choose Lucky Deck) vs Trials Around Reversal: -4, -2, 0, 2, 4

High volatility increases episodic choice

On incongruent trials...

Incongruent Trials		Episodic Choice
Lucky	+ ... < 50¢	Choose
Not Lucky	+ ... > 50¢	Choose

...choices are more episodic when volatility is high

Episodic Based Choice Index vs Low/High Environment

...and episodic choices take longer.

Reaction Time (ms): Inc. Based, Episodic Based

Behavior is best described by a Bayesian learner with hybrid choice

Bayesian learner + hybrid choice model

- Incremental value is updated by reward prediction error
$$V_{t+1} = V_t + \alpha_t(R_t - V_t)$$

- Learning rate is updated by uncertainty
$$\alpha_t = CP_t + (1 - CP_t)RU_t$$

- Uncertainty consists of *relative uncertainty* and change point probability
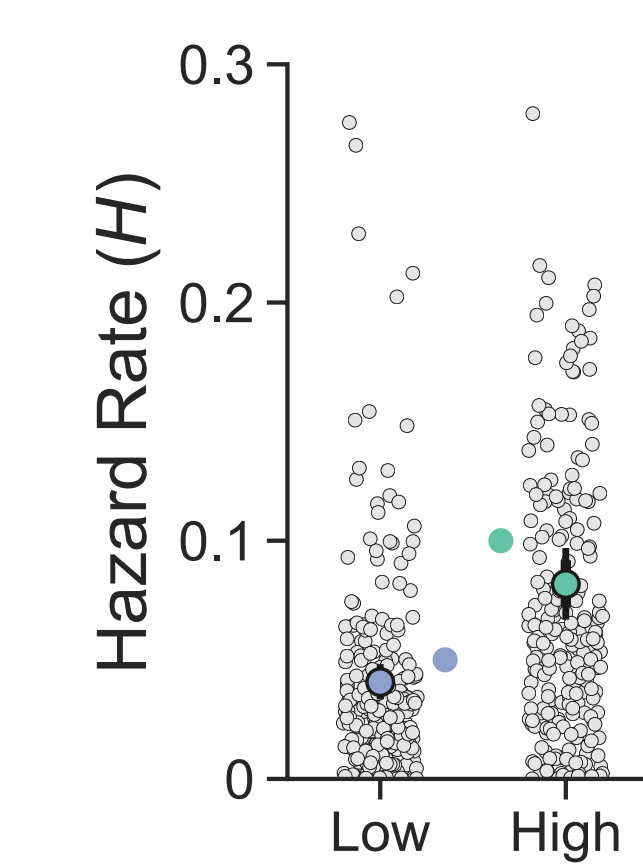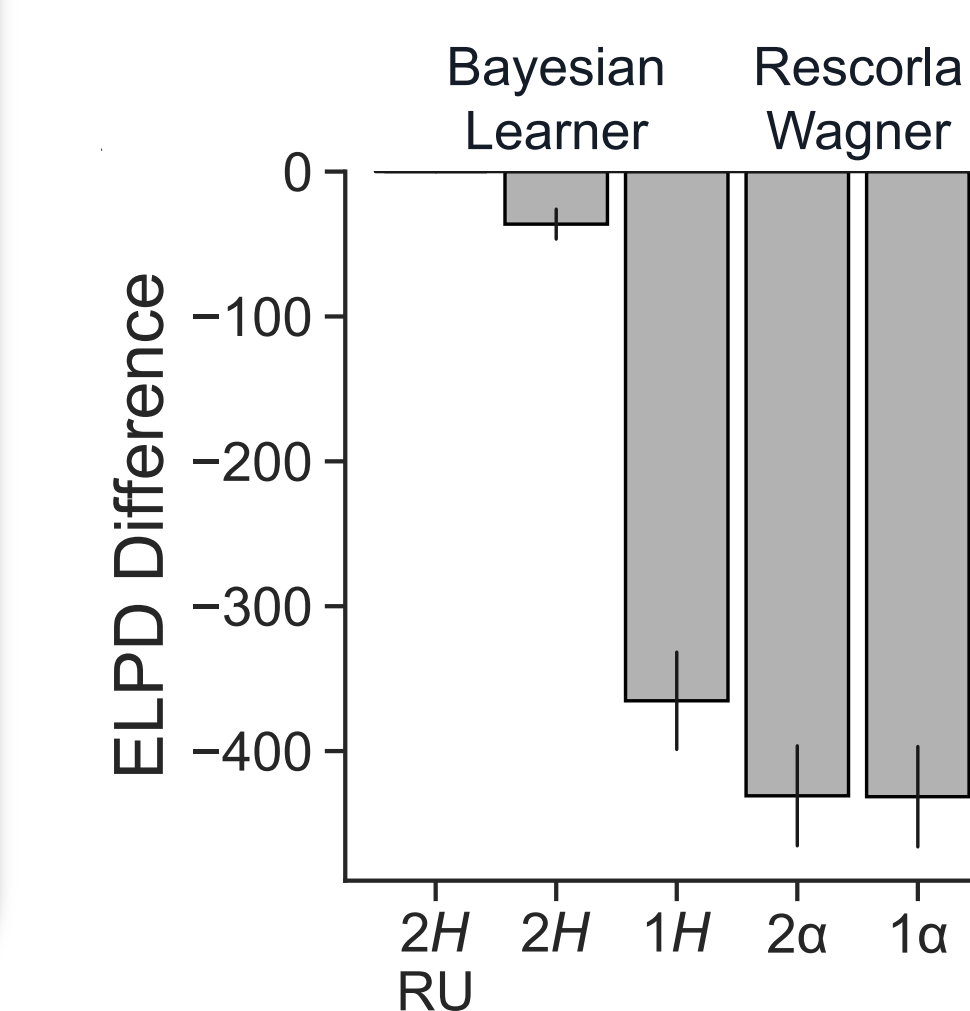$$RU_{t+1} = \frac{Unc.\ about\ V_t}{Unc.\ about\ V_t + \sigma^2}$$

- Hybrid choice consists of:
1. Inc. bias
2. Inc. value sensitivity
3. Ep. bias
4. Ep. value sensitivity
5. *Ep. value X RU sensitivity*

$$p(Choice_t) = logit^{-1}(\beta_0 + b_{0,s} + (\beta_1 + b_{1,s})V_t + (\beta_2 + b_{2,s})Old_t + (\beta_3 + b_{3,s})OV_t + (\beta_4 + b_{4,s})OV_t \times RU_t)$$
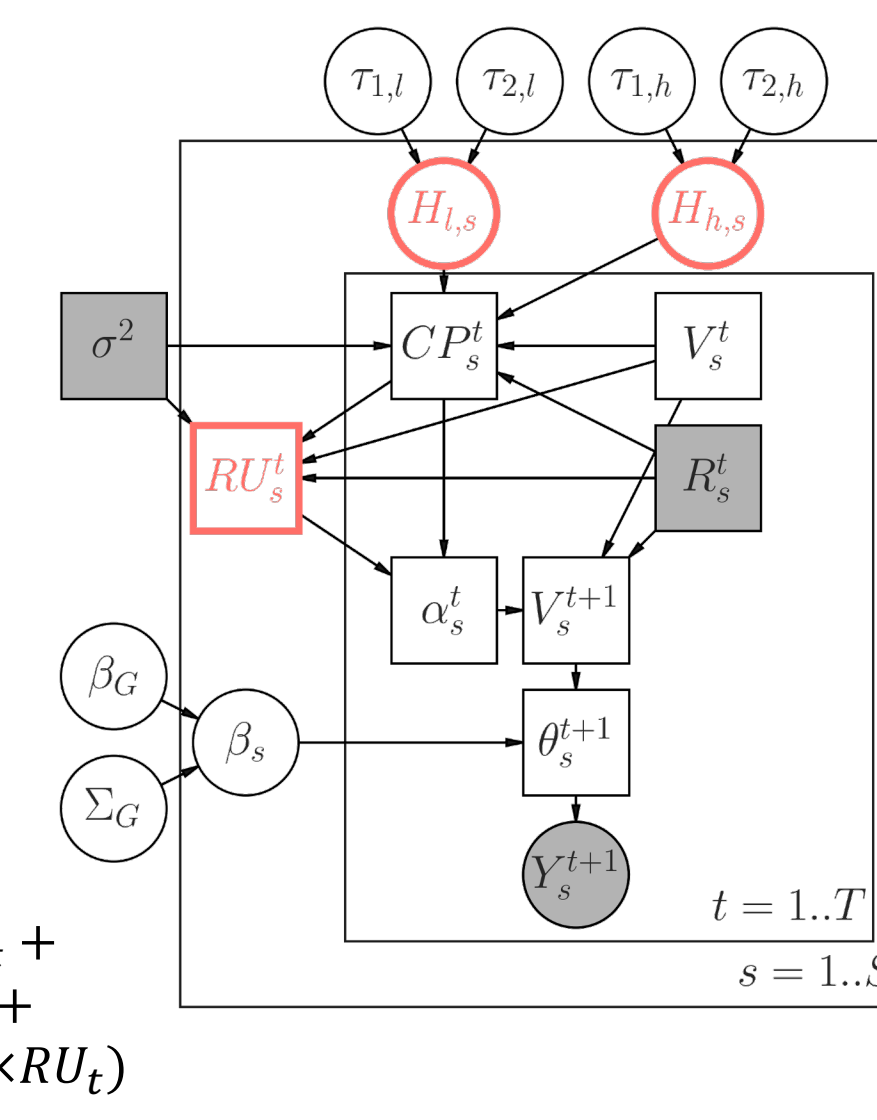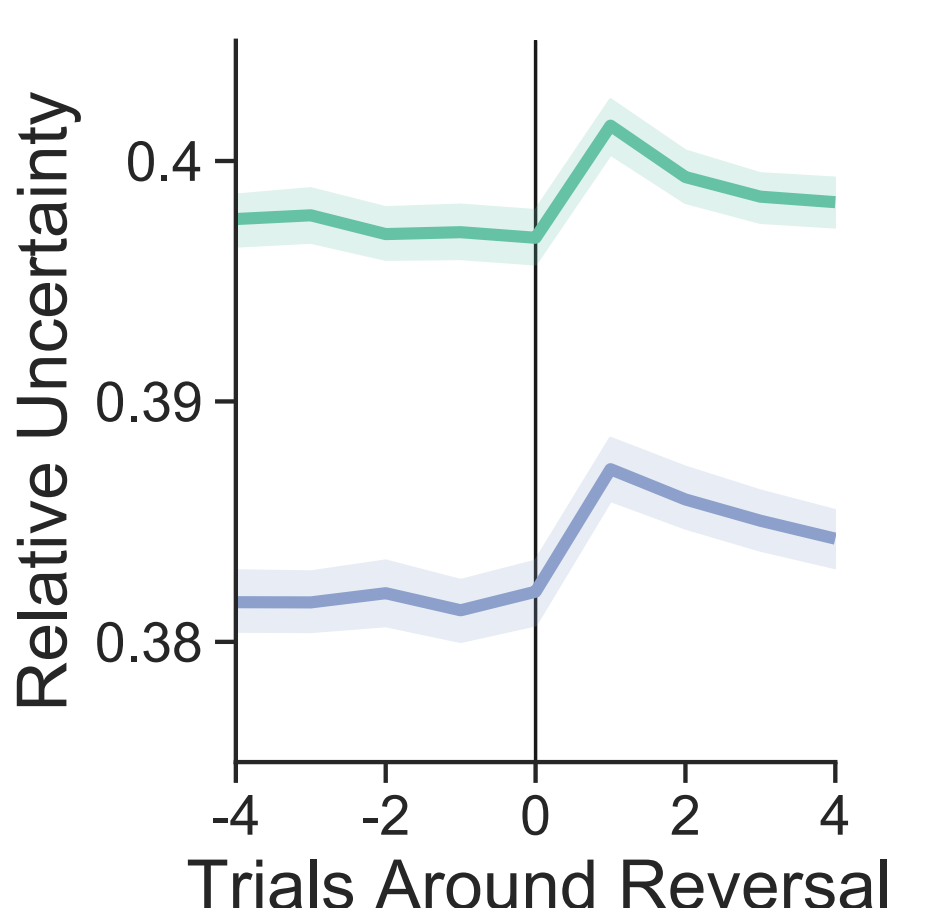

Built upon Nassar et al., 2010. All priors excluded for concision.

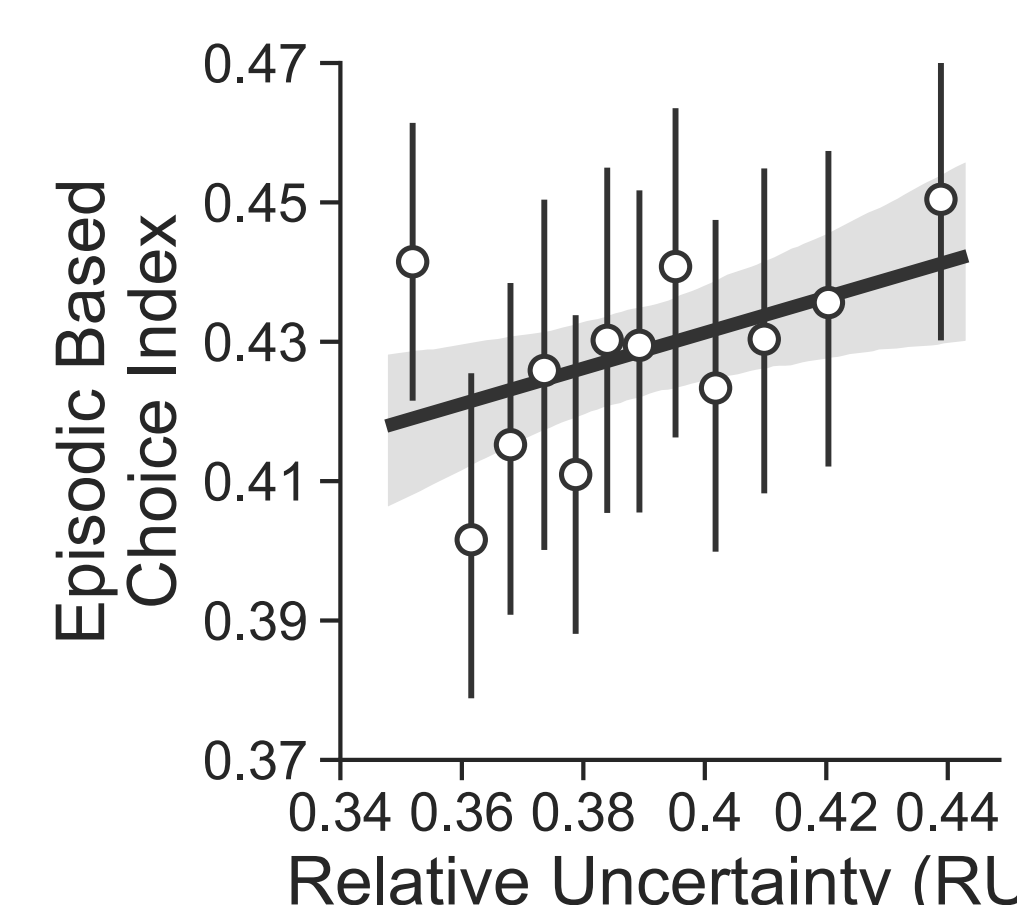**Participants are impacted by the volatility manipulation**

ELPD Difference — Bayesian Learner / Rescorla Wagner: 2H RU, 2H, 1H, 2α, 1α

Hazard Rate (H) vs Low / High

...and relative uncertainty increases after reversals.

Relative Uncertainty vs Trials Around Reversal: -4, -2, 0, 2, 4

Episodic choices increase with uncertainty

Choices are more episodic under greater uncertainty

Episodic Based Choice Index vs Relative Uncertainty (RU)

...and are more sensitive to episodic value under uncertainty.

Episodic: Bias, Value, Val. x RU Sensitivity — Estimate (Std.)
Incremental: Bias, Value Sensitivity — Estimate (Std.)
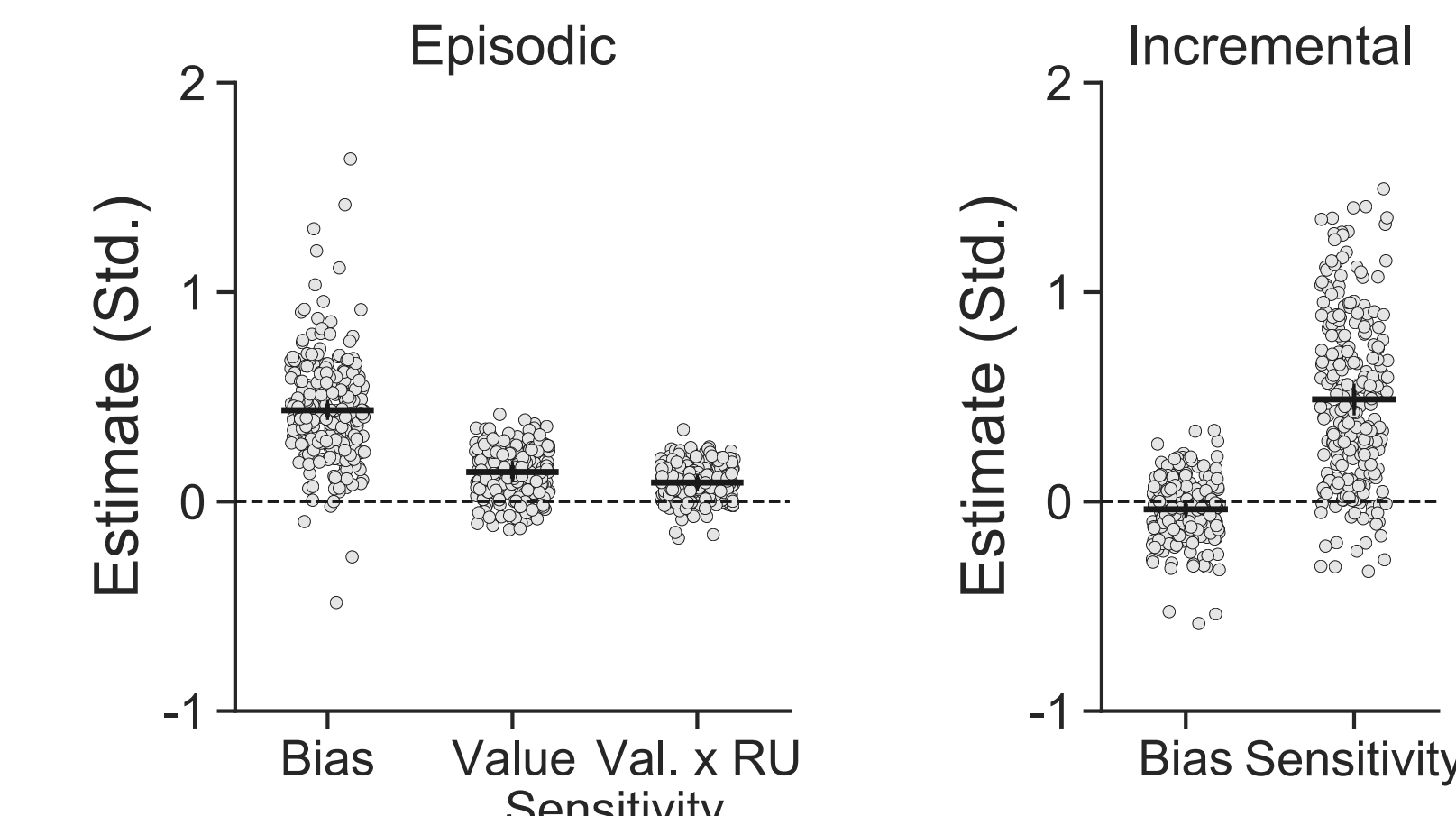
All results replicate

Choices were more episodic under uncertainty in a separate sample (n=223)

Episodic Based Choice Index vs Low/High Environment
Episodic Based Choice Index vs Relative Uncertainty (RU)
Episodic: Bias, Value, Val. x RU Sensitivity — Estimate (Std.)
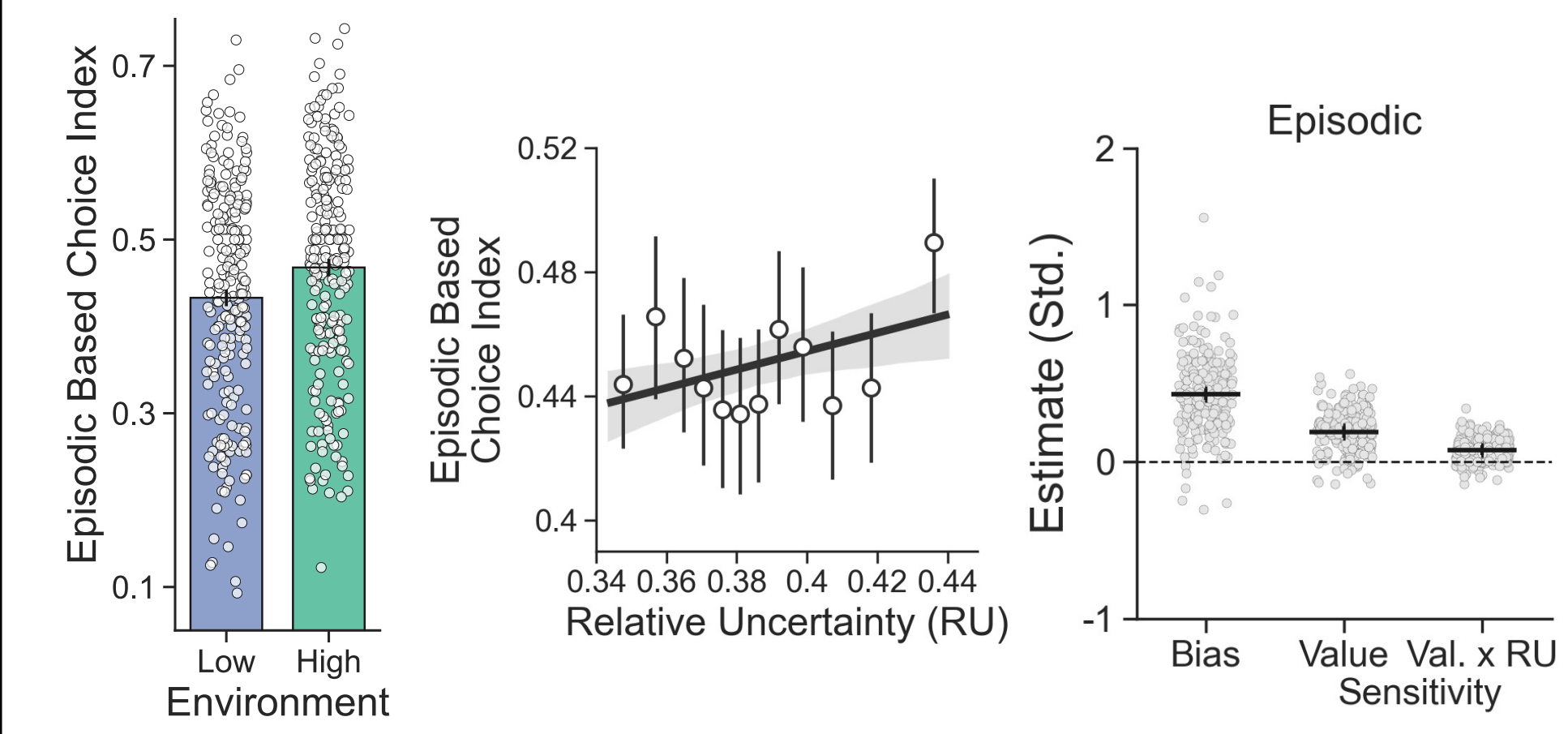
Take Home | Given the option, people recruit episodic memory for decisions made under more uncertain conditions.