Uncertainty-based arbitration between incremental and episodic control over decisions

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Code: github.com/boomsbloom/noisyoneshot

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Background

- Value-based decisions are typically thought to depend on average value constructed incrementally over many experiences with an option.
- Recent work suggests that decisions can also be made by consulting the value of a single episode.[1,2,3] When both incremental and episodic value are available, it is unclear when either source should be prioritized.
- Uncertainty may play an important role. Artificial agents benefit from single experiences when there is high uncertainty about average estimates.[4,5,6]

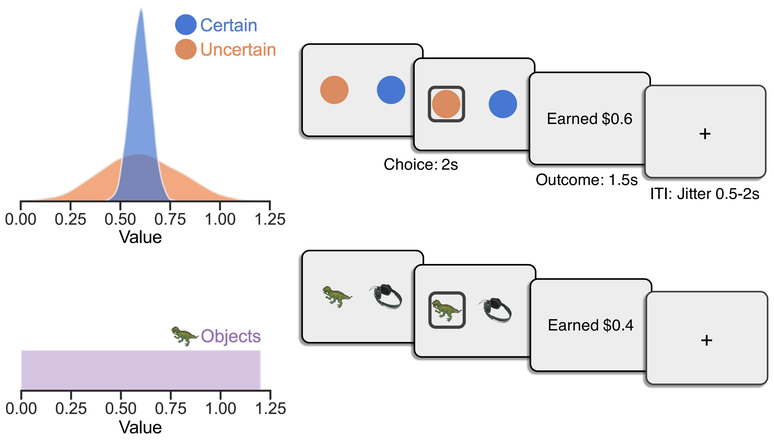
Does greater uncertainty around an average value increase the use of value encoded in a single shot?

Methods: Experiment One

*Will incremental uncertainty increase episodic control when each source of value is learned **separately**?*

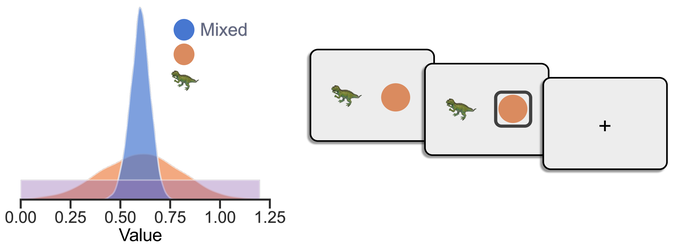
Learning Phase

- Trials consisted of separate choices between either incremental cues (circles with average value) or episodic cues (trial-unique objects).



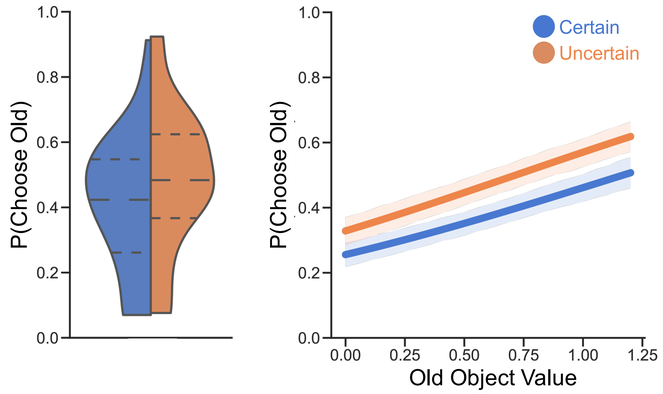
Decision Phase

- Following training, participants chose directly between the learned incremental cues and previously seen episodic cues.
- We predicted that participants would be more sensitive to the value of episodic cues when the incremental cue option was uncertain.



- 250 participants were recruited from Amazon Mechanical Turk.

Results: Experiment One



*P(Choose Old) ~ Old Object Value * Certainty + (Old Object Value * Certainty | Subject)*

Multilevel logistic regression model fit with MCMC

- Certain incremental cues were chosen more frequently than uncertain incremental cues ($ß_\mu$ = 0.20, 95% HDI = [0.12, 0.29]).
- More valuable episodic cues were chosen more frequently ($ß_\mu$ = 0.96, 95% HDI = [0.80, 1.12]).
- A reliable interaction between certainty and value was not observed ($ß_\mu$ = 0.04, 95% HDI = [-0.05, 0.12]).

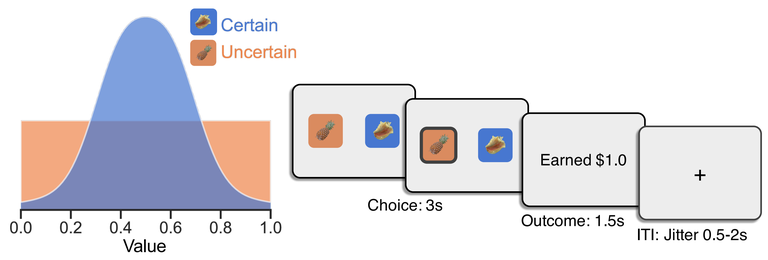
Results suggest that participants use both incremental and episodic sources of value, but do not integrate them when learned separately.

Methods: Experiment Two

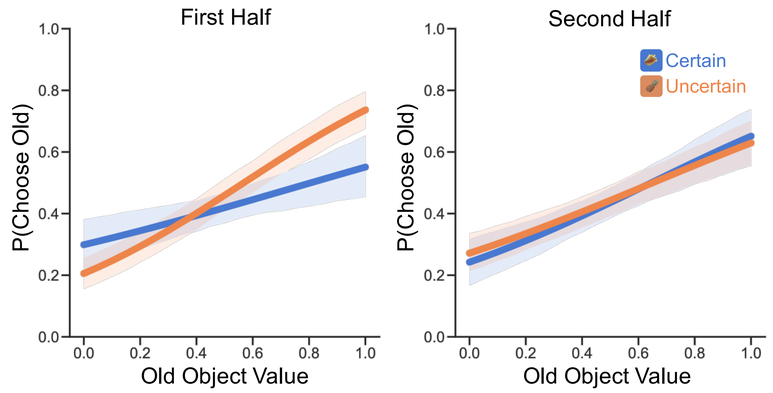
*Will incremental uncertainty increase episodic control when each source of value is learned **simultaneously**?*

Learning and Decision Phase

- Based on experiment one, we developed a second experiment that integrated incremental and episodic sources of value in a single cue.
- Participants chose between two ”card decks”, each with its own average value and trial-unique objects.
- Objects from the previous 5-30 trials could be repeated a single time.
- 100 participants were recruited from Amazon Mechanical Turk.



Results: Experiment Two



*P(Choose Old) ~ Old Object Value * Certainty * Time + (Old Object Value * Certainty * Time | Subject)*

Multilevel logistic regression model fit with MCMC

- More valuable repeated objects were chosen more frequently ($ß_\mu$ = 1.69, 95% HDI = [1.30, 2.11]).
- More valuable repeated objects were chosen more often when the deck was uncertain ($ß_\mu$ = -0.27, 95% HDI = [-0.55,-0.01]).
- This interaction was observed to depend on when choices occurred during the experiment ($ß_\mu$ = 0.40, 95% HDI = [0.16, 0.66]).

Results support the hypothesis that humans are likely to use value encoded in a single shot when average value is more uncertain.

Conclusions

- Incremental and episodic sources of value do not appear to compete for control over decision making when learned separately.
- When both sources of value are learned from the same cue, participants engage in greater episodic control when it is difficult to construct veridical average value.
- This suggests that humans sample individual episodes for value-based decisions according to a tradeoff between computational expense and noisy estimation.

References & Acknowledgements

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[5]Blundell, C. et al. (2016) *arXiv:1606.04460*
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Software: Python (jupyter, numpy, pandas, seaborn, pymc3, bambi), JavaScript (jsPsych), Apache HTTP Server

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