Uncertainty-based arbitration between incremental and episodic control over decisions

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Background

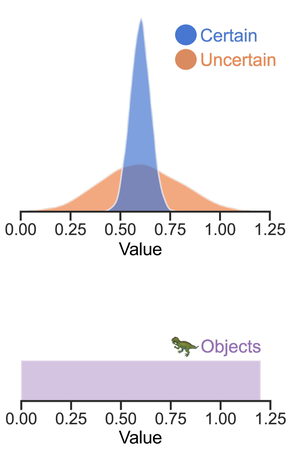
- Decisions between two familiar options can be made by consulting value averaged over many episodes or value from a single episode
- Artificial agents benefit from single experiences when there is high uncertainty about incrementally constructed value[1,2,3]

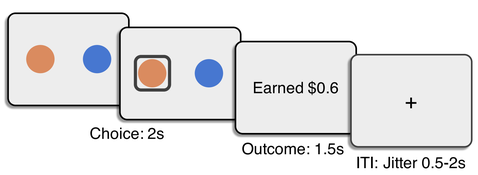
Do humans use value encoded in a single shot when average value is more uncertain?

Methods: Experiment One

Training Phase

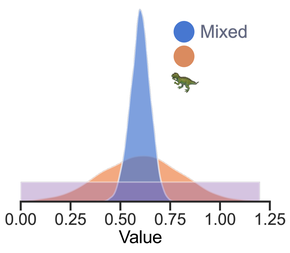
- Trials consisted of separate choices between either incremental cues (circles with average value) or episodic cues (trial-unique objects)
- Each cue's value was learned over 300 trials split between choice type

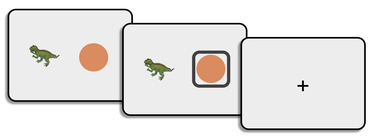




Testing Phase

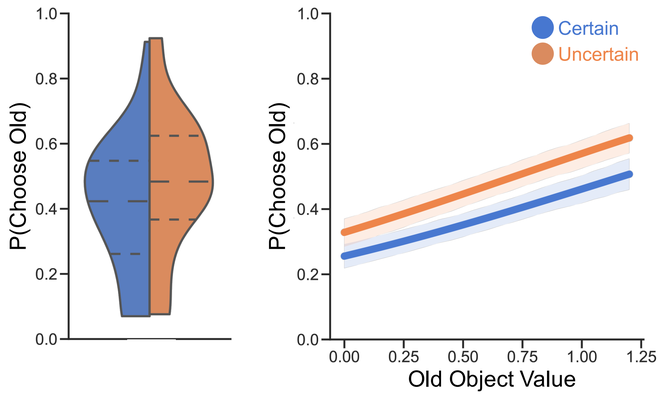
- Following training, participants chose directly between the learned incremental cues and previously seen episodic cues over 150 trials
- We predicted that participants would be more sensitive to the value of episodic cues when the incremental cue option was uncertain





- 250 participants were recruited from Amazon Mechanical Turk

Results: Experiment One



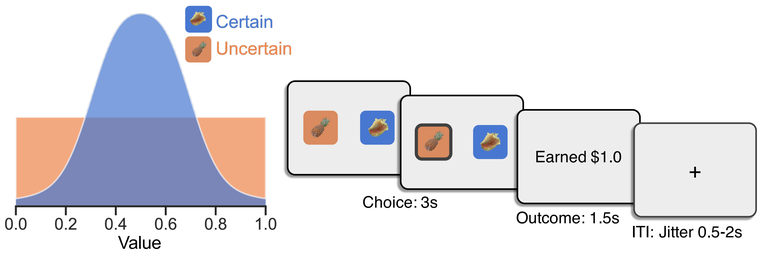
*P(Choose Old) ~ Old Object Value * Certainty + (Old Object Value * Certainty | Subject)*

- 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

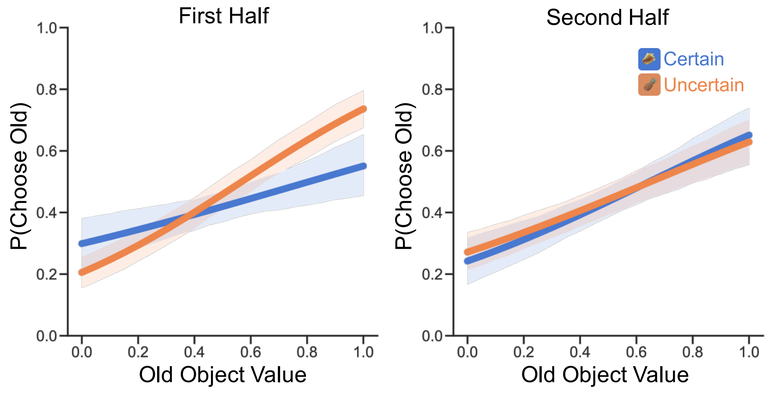
Methods: Experiment Two

Single Integrated 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 over 180 trials
- 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)*

- 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 more 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

[1]Lengyel, M. & Dayan, P. (2008) *Advances in Neural Information Processing Systems 20*:889–896
[2]Blundell, C. et al. (2016) *arXiv:1606.04460*
[3]Santoro, A., Frankland, P.W., & Richards, B.A. (2016) *Journal of Neuroscience 36*(48), 12228–12242

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Software: Python (jupyter, numpy, pandas, seaborn, pymc3, bambi), JavaScript (jsPsych), Apache HTTP Server

Email: jonathan.nicholas@columbia.edu | Code: github.com/boomsbloom/noisyoneshot