Value-based decisions are supported by episodic memory but not incremental learning in patients with cerebellar ataxia

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Background

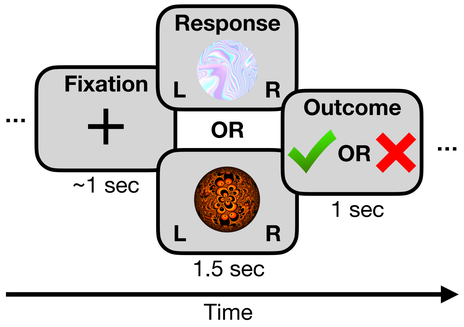
- **Recent animal work suggests that the cerebellum may play an unappreciated role in incremental reward learning[1,2].**
- **Cerebellar ataxia provides an opportunity to test whether lesions of the cerebellum impair incremental reward learning in humans.**
- **Episodic memory is also used for reward learning[3,4,5], and is likely independent of the cerebellum.**

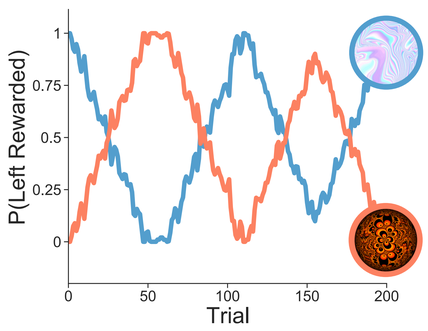
Primary Question | **Is the cerebellum necessary for incremental reward learning but not reward learning from episodes?**

Methods

- **19 patients with cerebellar ataxia and 57 age- and sex-matched controls (3/patient) participated in two experiments.**

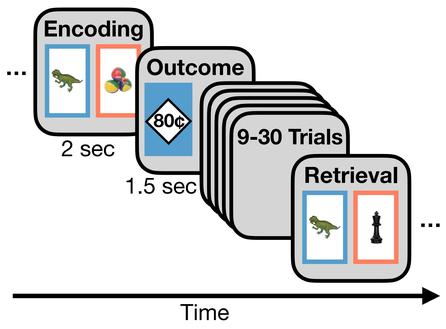
Experiment 1: Assessing Incremental Learning

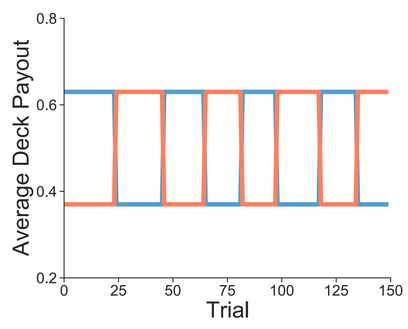




- **Participants saw one of two cues and pressed with either their left or right hand to receive probabilistic binary feedback that drifted over time.**

Experiment 2: Adding Episodic Memory

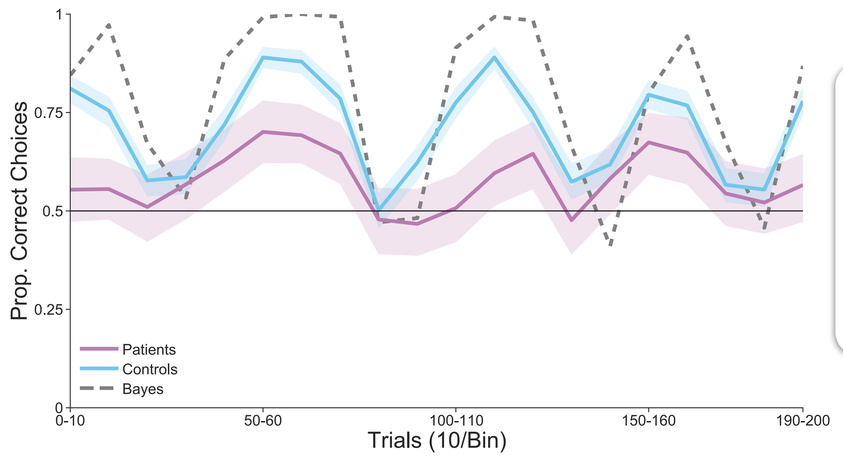




- **Participants chose between two decks of cards that featured trial-unique objects and received reward. Decks reversed in expected value periodically.**
- **Objects could repeat once after 9-30 trials and were worth the same amount.**
- **Participants later completed a standard subsequent memory test for objects.**

Patients are impaired at incremental reward learning relative to controls

Patients hardly learn button mappings



...and their behavior is not well fit by a model of incremental reward learning.

Q Learner

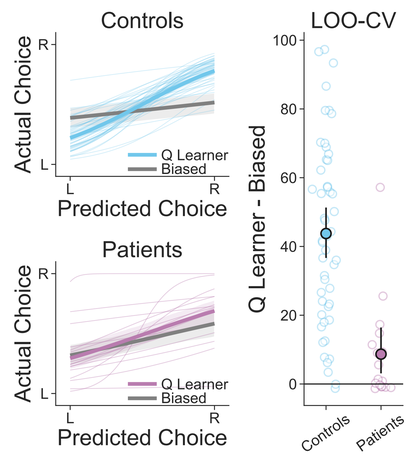
$$Q_{h,t+1} = Q_{h,t} + \alpha(Q_{h,t} - r_t)$$

$$p(L_t) = \phi(\beta(Q_{L,t} - Q_{R,t}))$$

$$\phi(x) = \frac{1}{1+e^{-x}}$$

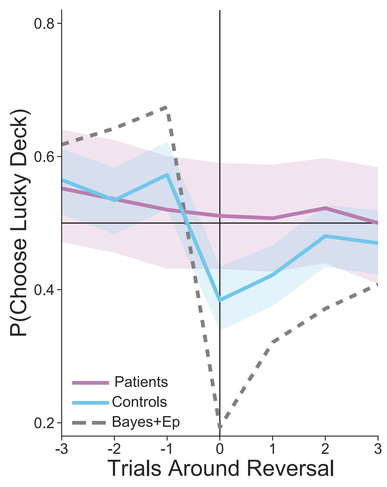
Biased Responder

$$p(L_t) = \phi(\beta)$$

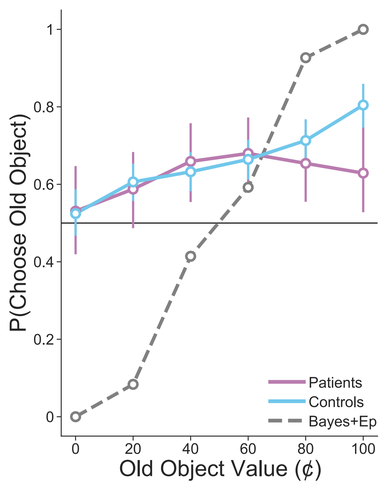


Patients base decisions on episodic memory but not incremental reward

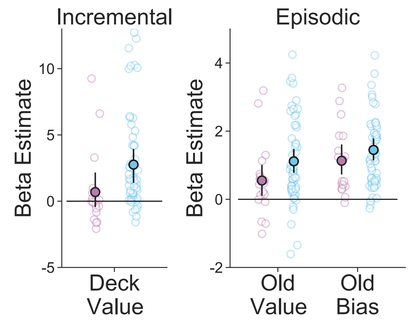
Patients are not sensitive to reversals in deck value



...but are sensitive to single experiences.



This is confirmed by a hybrid learning model

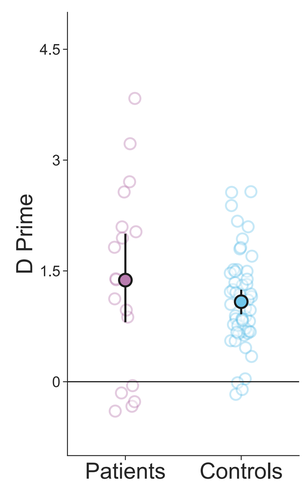


Q Learner + Hybrid Choice

$$Q_{d,t+1} = Q_{d,t} + \alpha(Q_{d,t} - r_t)$$

$$p(Red_t) = \phi(\beta_1(Q_{red,t} - Q_{blue,t}) + \beta_2(OldValue) + \beta_3(OldDeck))$$

...and similar subsequent memory to controls.



Take Home

The cerebellum is necessary for learning about reward incrementally but not from episodes.

References and Acknowledgements

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