Modulation of Learning by The Integration of Common and Separate Prediction Errors

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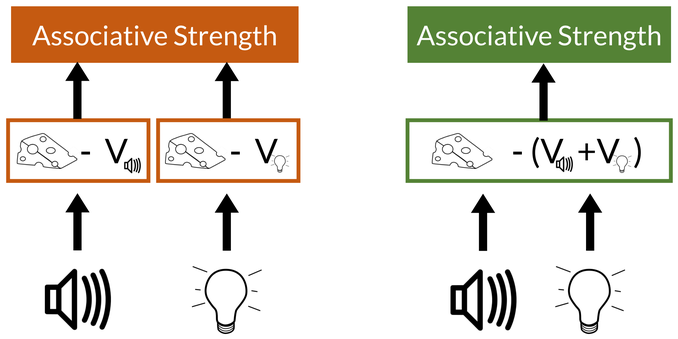
BACKGROUND

How do we learn about rewarding cues in complex environments ?

- Answer 1 : through separate streams of information (separate error model).
- Answer 2 : through a common representation of of information (common error model).



Separate PE (Bush & Mosteller, 1955)

Common PE (Rescorla & Wagner, 1972)

- While a large body of literature favors the **common PE** paradigm, recent evidence challenged the **common PE** assumption by showing that **separate PEs** *also play a significant role in learning* (Rescorla 2000, 2001; Le Pelley 2004; Leung & Westbrook 2008).
- **The goal is to explore possibilities of how both PEs integrate and validate those models with experimental data.**

METHODS

- We need a task that is able to pit the two theories against one another.
- Rats (N=24) were trained in 3 separate replications. Rats were trained to self-initiate trials by performing a response (a nose-poke into nose port) after receiving 20s cue signaling trial availability.
- 10s visual (A & B) and auditory (X & Y) stimuli were used as CSs in a delay conditioning procedure. The US was 10% sucrose solution available for 3s. Trials were pseudo-randomly sequenced and separated by a 10s inter-trial interval.

Stage 1	4A+,	4B-,	**3X+**,	1X-,	**3Y-**,	1Y+
Stage 2	4A+,	4B-,	**3AX+**,	1X-,	**3BY-**,	1Y+

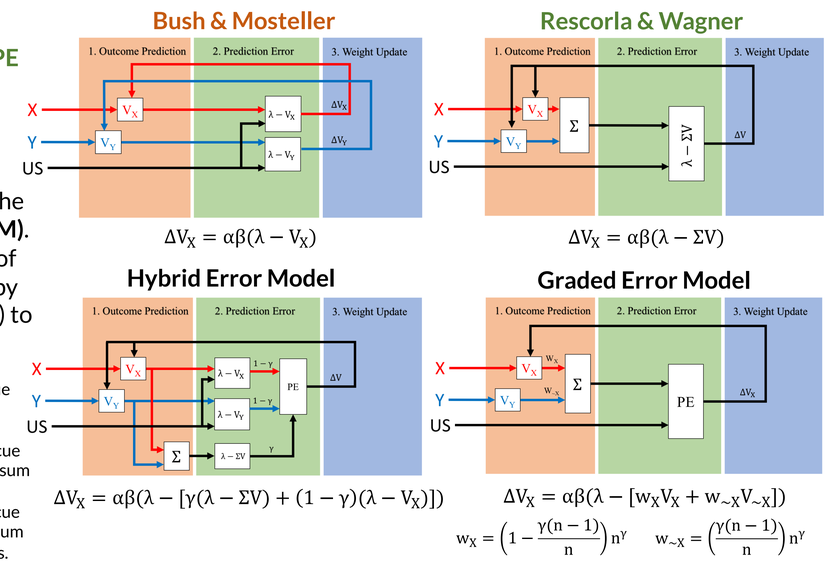
- Response was measured as the percentage of time spent in the nose poke (signaling anticipation of reward).

THEORITICAL POSSIBILITIES OF PEs INTEGRATION

- We can describe PEs integration as a point in a spectrum with **common PE** paradigm in one end and **separate PE** in the other end.
- We suggest the **Hybrid Error Model (HEM)** and the **Graded Error Model (GEM)**.
- In both models, the level of integration is controlled by γ that ranges from 1 (RW) to 0 (BM).

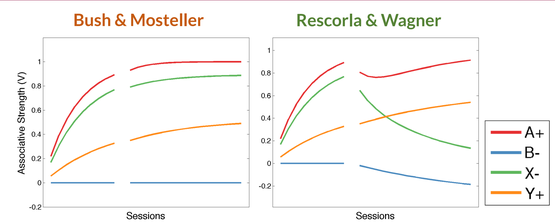
Blocking explanations (A+/AB+):

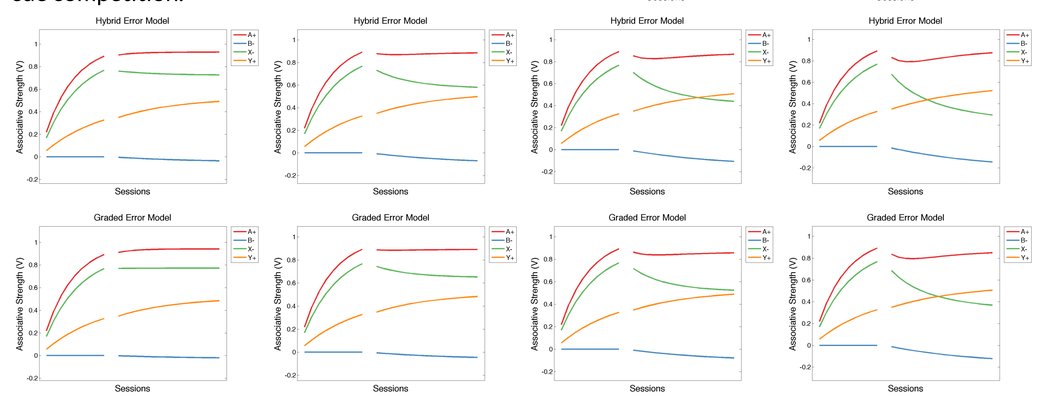
- RW: Conditioning to the blocked cue (B) is prevented by the already-predictive blocking cue (A).
- HEM: Conditioning to the blocked cue (B) is modulated by the γ-weighted sum of B and AB prediction errors.
- GEM: Conditioning to the blocked cue (B) is modulated by the γ-weighed sum of B and non-B outcome predictions.



Model PREDICTIONS

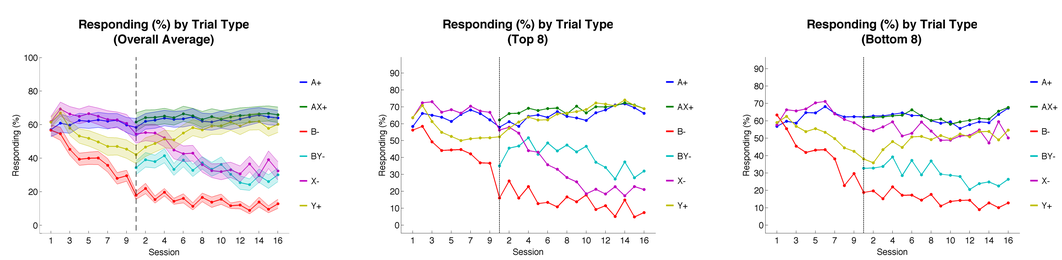
- In stage 2, **Separate PE** paradigm predicts that X > Y while **common PE** paradigm predicts that Y > X.
- In both Hybrid Error Model (HEM) and Graded Error Model (GEM), gamma value modulates cue competition.





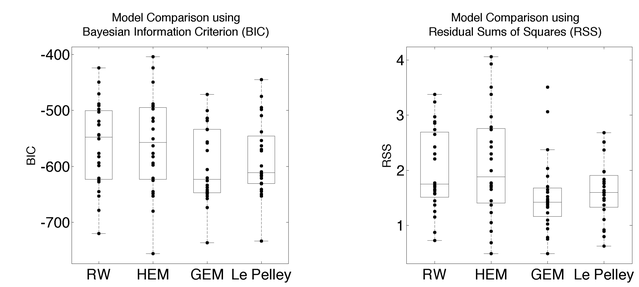
RESULTS

- Most rats solved the discrimination. However, there is a high variability.
- Left panel shows the overall average of behavioral data. The middle panel shows the average behavior from top 8 discriminators wile the right panel highlights the bottom discriminators.
- In the bottom discriminators, rats did not discriminate between X and Y while at the same time they succeeded at the other discriminations.



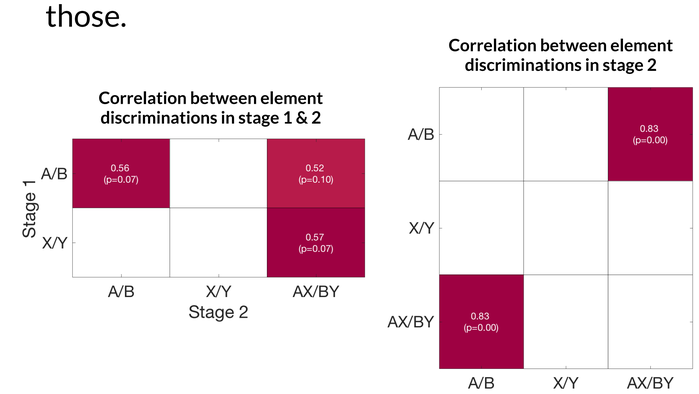
MODELING & FITTING

- For each animal, RW, HEM, GEM and Le Pelley's hybrid model were used to fit learning curves of individual rats.
- Bayesian Information Criterion (BIC) shows that the individual animal data are best explained by the Graded Error Model (GEM).



DISCUSSION

- Can slow learning or a more general discrimination deficit explain those results ?
- **Answer:** Rats still discriminated A/B and AX/BY with no correlation between X/Y and any of those.



CONCLUSIONS

- Influential learning models cannot account for the reported results, suggesting the need for an integrated approach to common and separate PE.
- Learning about rewarding cues in complex environments is best explained as a weighted sum of common and separate PE.

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