# Reward prediction errors enhance episodic memory

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## 1. INTRODUCTION

Similar dopaminergic inputs to ventral striatum and hippocampus suggest a link between reward learning and episodic memory (Shohamy & Adcock, 2010).

Reward motivation amplifies hippocampal activation and episodic memory for expectancy violations (Murty & Adcock, 2013).

Large prediction errors ("jumps") create new memory traces whereas gradual changes are integrated into a previous memory trace (Gershman et al., 2014).

**reward prediction errors** → **signed effects on memory?** / **unsigned effects on memory?**

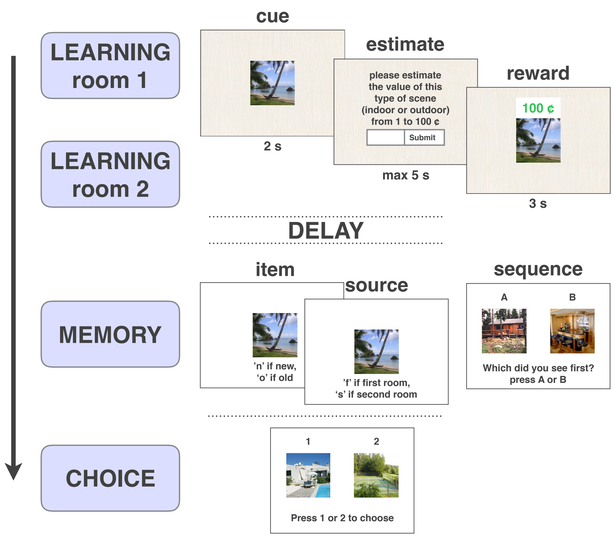
**Present study**: In three experiments, we investigated whether a higher variance context ('risk' ), modulates learning and episodic memory for events at reward outcome.

**greater absolute prediction errors during reward outcome** → **enhanced encoding** → **better episodic memory**

## 2. TASK DESIGN

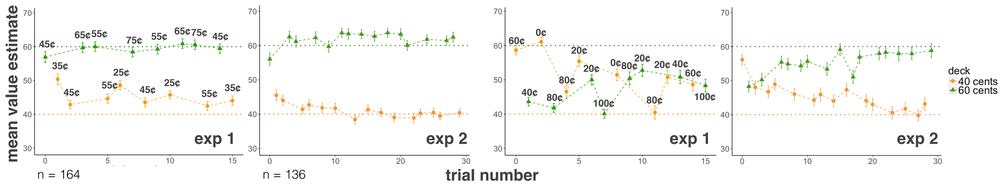
| Decks (indoor/outdoor) | Rooms: High Risk | Rooms: Low Risk |
|---|---|---|
| High Value | Exp 1, 2: μ = 60¢; σ = 37¢, 32¢<br>Exp 3: μ = 80¢; σ = 16¢ | Exp 1, 2: μ = 60¢; σ = 13¢, 16¢<br>Exp 3: μ = 80¢; σ = 8¢ |
| Low Value | Exp 1, 2: μ = 40¢; σ = 37¢, 32¢<br>Exp 3: μ = 20¢; σ = 16¢ | Exp 1, 2: μ = 40¢; σ = 13¢, 16¢<br>Exp 3: μ = 20¢; σ = 8¢ |

# trials in each cell
Exp 1: 8 trials
Exp 2-3: 15 trials




## 3. LEARNING

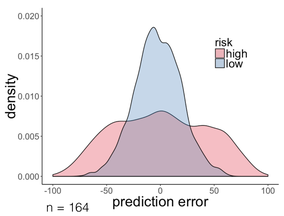
### Low Risk / High Risk




**Exp 1 & 2 (replicated in 3).** participants learned the average values of the high and low decks better in the low risk than in the high risk room; exp 1: $t(163) = 14.52$, $p < 0.001$, exp 2: $t(135) = 13.11$, $p < 0.001$. (cent values represent reward received on that trial in exp 1; rewards randomized in exp 2 & 3).

### Prediction Error

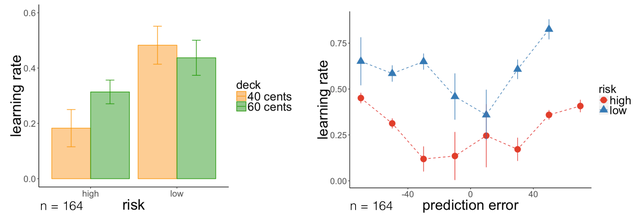
**Reward[i]** − **Estimate[i]** = **Prediction Error**



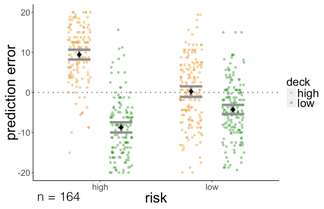

**Exp 1 (replicated in 2&3).** there were higher absolute prediction errors experienced in the high risk room; $t(163) = 36.77$, $p < 0.001$.

### Learning Rate

**V[i+1] = V[i] + lr(Prediction Error)** → **Learning Rate (V[i+1] - V[i])/(PE)**



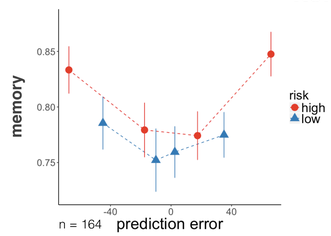

**Exp 1 (replicated in 2&3).** there were higher learning rates in the low risk room and in both rooms, higher absolute prediction errors increased learning rate; absolute prediction error: t = 3.30, p = 0.001, β = 0.07; risk: t = 4.67, p < 0.001, β = 0.16.



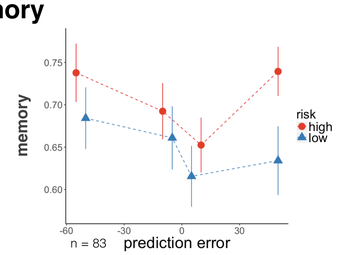

**Exp 1 (replicated in 2&3).** there was an interaction between risk and deck value, such that the low value deck was overestimated and the high value deck was underestimated more so in the high versus the low risk room; $F(1,163) = 141.2$, $p < 0.001$.

## 4. MEMORY

### Item Memory

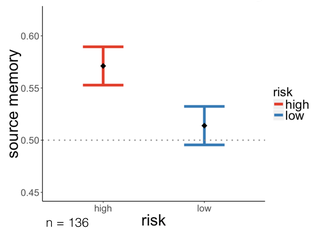



**Exp 1 (replicated in 2).** higher absolute prediction errors improved memory for items experienced at reward outcome; absolute prediction error: z = 3.36, p < 0.001, β = 0.23; risk: z = 0.9, p = n.s., β = 0.10.



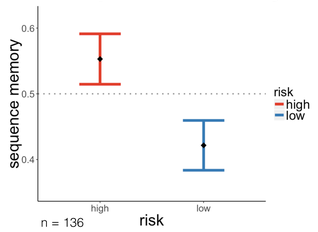

**Exp 3.** with a similar range in prediction errors, there were separate effects of absolute prediction error and risk (context) in enhancing item memory; absolute prediction error: z = 2.24, p = 0.02, β = 0.12; risk: z = 2.58, p = 0.009, β = 0.24.

### Source Memory



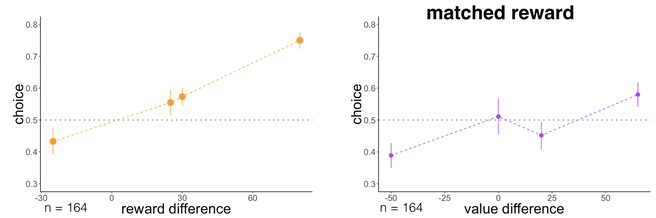

**Exp 2.** a high risk context led to better source memory; z = 2.05, p = 0.04, β = 0.25.

### Sequence Memory




**Exp 2.** a high risk context led to better sequence memory; z = 2.70, p = 0.006, β = 0.56.

## 5. CHOICE




**Exp 1.** participants chose the items associated with a higher reward outcome; z = 6.40, p < 0.001, β = 0.54.

**Exp 1 (replicated in 2&3).** when reward outcomes were matched between options, participants chose the items they had initially valued more; z = 3.74, p < 0.001, β = 0.30.

## 6. CONCLUSION

**Learning**

- ↑Absolute Prediction Errors → ↑Learning Rate
  - ⇨ unexpected uncertainty increases learning rate (LC-NE system?) (Payzan-LeNestour et al, 2013; Hayden et al, 2011, Behrens et al 2007)
- Low Risk Context → ↑Learning Rate
  - ⇨ prediction errors scale to risk context (Diederen et al, 2016)

**Memory**

- ↑Absolute Prediction Errors → ↑Item Memory
- High Risk Context → ↑Episodic Memory
  - ⇨ arousing events, like unexpected outcomes improve memory (LC-NE system?) (Mather & Sutherland, 2011)

**Choice**

- ↑Reward → ↑Choice
- ↑Value → ↑Choice
  - ⇨ memories for value (not just recognition) predict choice (Murty et al, 2016)