Not smart enough: most rats fail to learn a parsimonious task representation

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Motivation and Research Question

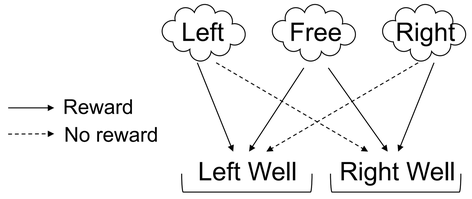
- As experimenters designing tasks for laboratory animals, we often assume that animals represent the task as we understand it. This assumption may be wrong.
- To explore whether and how animals can learn implicitly, without instructions, task representations that are aligned with the true rules or structure of the environment.

The odor-guided choice task

17 well-trained rats (161 sessions in total)
from Takahashi et al. (2016) and Roesch et al. (2009).

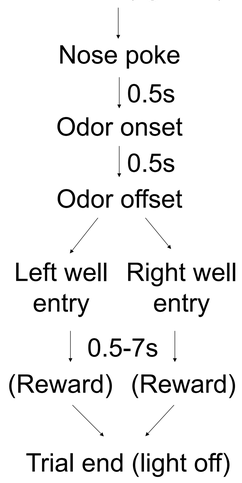
Experiment apparatus

Example session



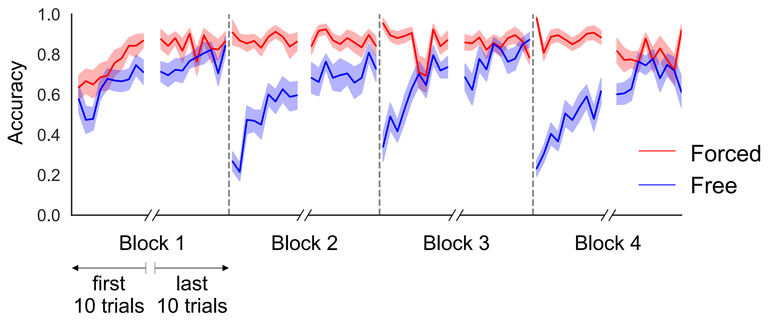
Unsignaled	Left Well	Right Well
Block 1	**Short**	Long
Block 2	Long	**Short**
Block 3	**Big**	Small
Block 4	Small	**Big**

Trial timeline



Choice behavior shows learning

Forced-choice accuracy remained high throughout session;
Free-choice accuracy dropped after block changes, but increased within each block.



The reinforcement learning model

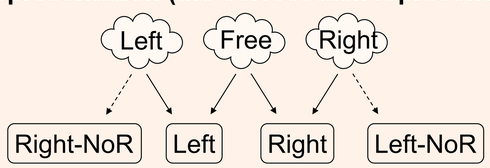
Rescorla-Wagner learning with a side bias term per animal

$$V_{t+1}(\text{state}) = V_t(\text{state}) + \eta\left(R_t \cdot \gamma^{\text{delay}} - V_t(\text{state})\right)$$

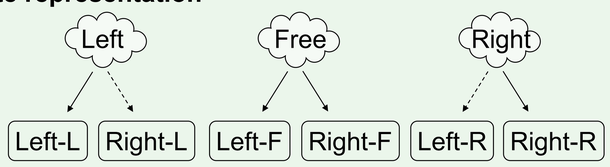
$$P(\text{left}) = \frac{1}{1 + e^{-\beta(V(\text{state}_{\text{left}}) - V(\text{state}_{\text{right}})) - \text{sb}}}$$

Alternative state representations

(1) Four-state representation (the correct task representation)

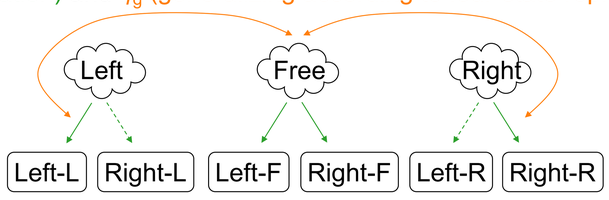


(2) Six-state representation



Hybrid representations

(3) Hybrid-learning: two learning rates η (learning under six-state representation) and η_g (generalizing according to four-state representation)

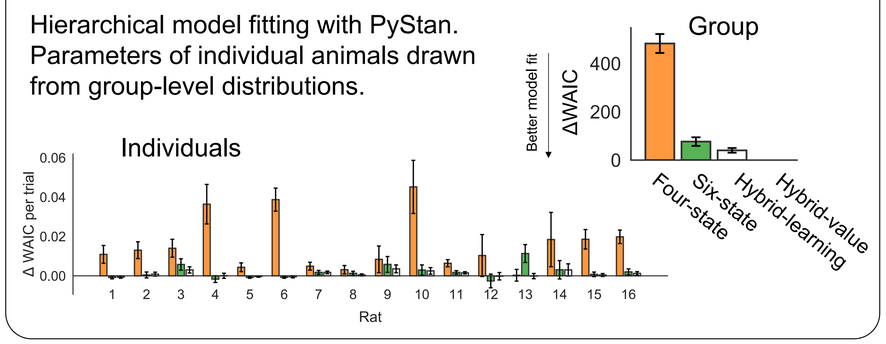


(4) Hybrid-value: $V_{\text{hybrid}} = wV_{\text{4-state}} + (1-w)V_{\text{6-state}}$

Model fitting and comparison

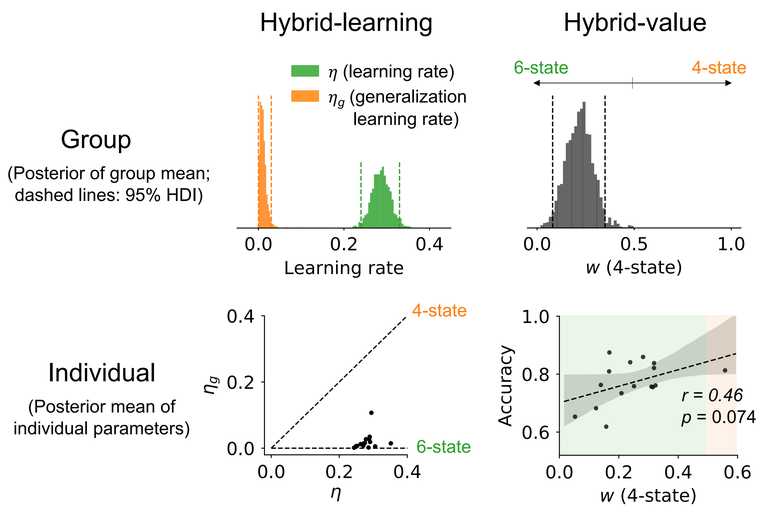
Evidence supports the six-state representation

Hierarchical model fitting with PyStan.
Parameters of individual animals drawn from group-level distributions.



Parameter estimates in hybrid models

Higher learning rate and weight for six-state than four-state (both group- and individual-level)



Individuals use six- or four-state representations to different extent

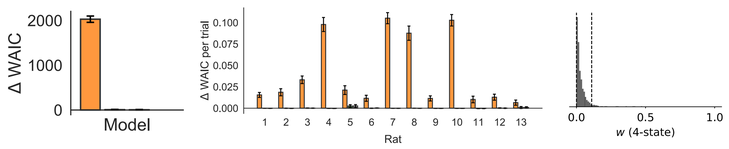
Conclusions

- Most rats failed to acquire the shared reward representation, even though this knowledge could have helped them learn faster and make better choices.
- Individual difference in task representation (the extent to which partial knowledge was acquired).

Future directions

- How is the (partial) knowledge of task presentation acquired?
  - Requires data from the entire training experience (from the first training session to the well-trained stage)

Early training sessions show even stronger evidence for the six-state representation (n = 13)



- Explain individual difference in representation learning, i.e. why some animals are better at it than others.

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