



Decoding subjective decisions from the orbitofrontal cortex

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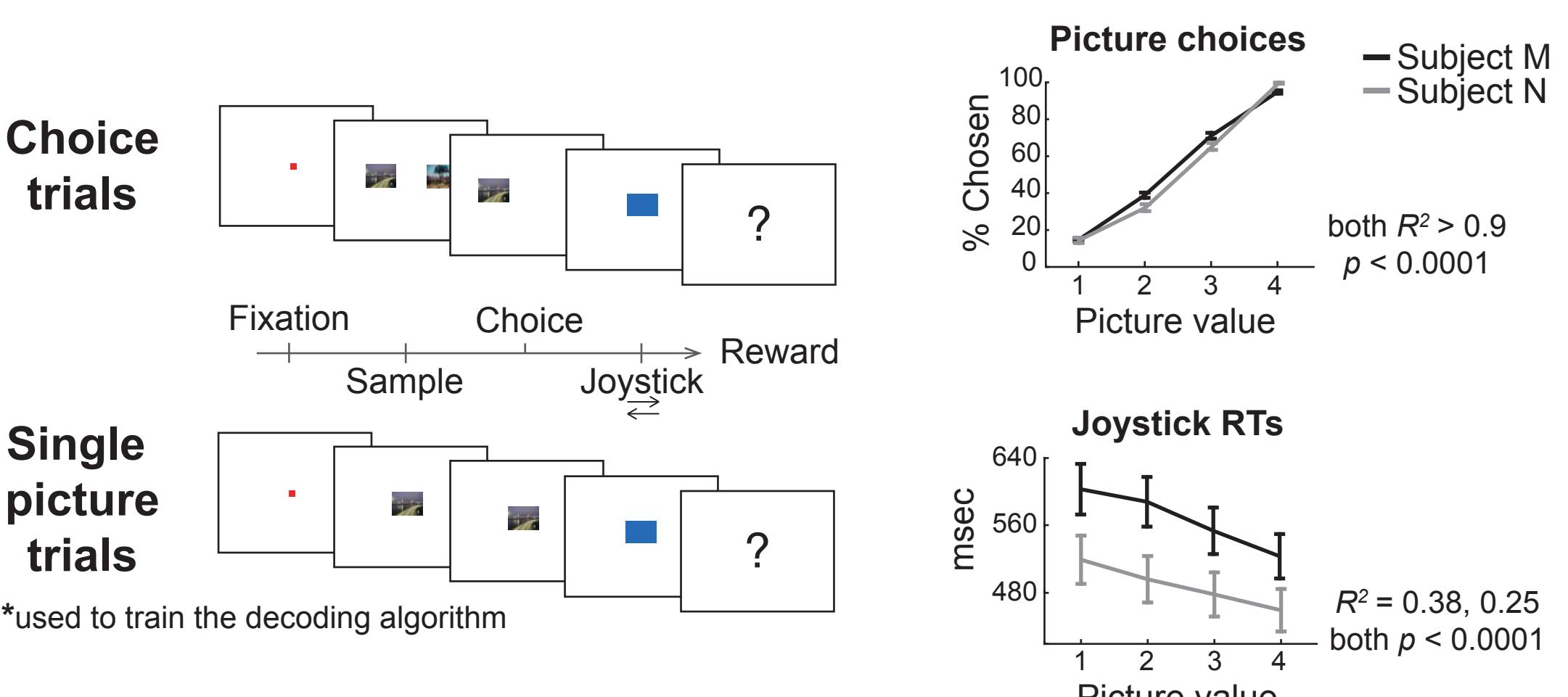
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Background

- During a subjective decision, it is believed that the brain computes a value for each option, then compares them to arrive at a choice¹⁻³.
- The orbitofrontal cortex (OFC) is critically involved in value-based decision-making⁴⁻⁶, but the neural mechanisms involved remain unclear.
- A major challenge is that evaluation and choice involve unobservable cognitive processes that can vary significantly trial-to-trial.
- Here, we use a novel approach to decode value representations from multidimensional OFC data on individual choice trials with high temporal resolution.

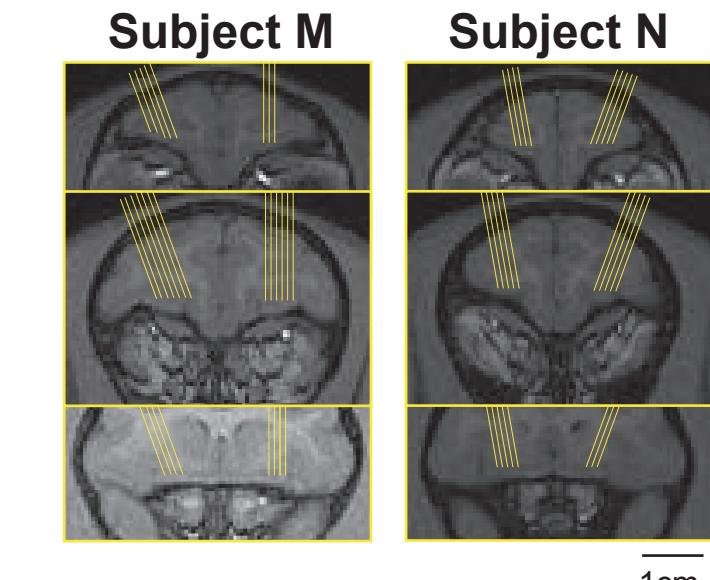
Reward Preference Task

- 8 familiar pictures predicted 4 reward values (amounts of fruit juice)
- Randomly interleaved trial types:
 - Choice trials** (17%) - Subject chose between 2 pictures
 - Single picture trials** (83%) - Subjects shown 1 picture
- Subjects had to execute an instructed joystick response to obtain reward



Neurophysiology and Analysis

- OFC recordings (44 sessions)
 - 451 Neurons (259 M, 192 N)
 - 455 LFPs (251 M, 204 N)
 - Average ensemble = 10 neurons + 10 LFPs
- Session-by-session choice decoding
 - Linear Discriminant Analysis (LDA) classified ordinal picture values (1 to 4), based on all recorded neural features



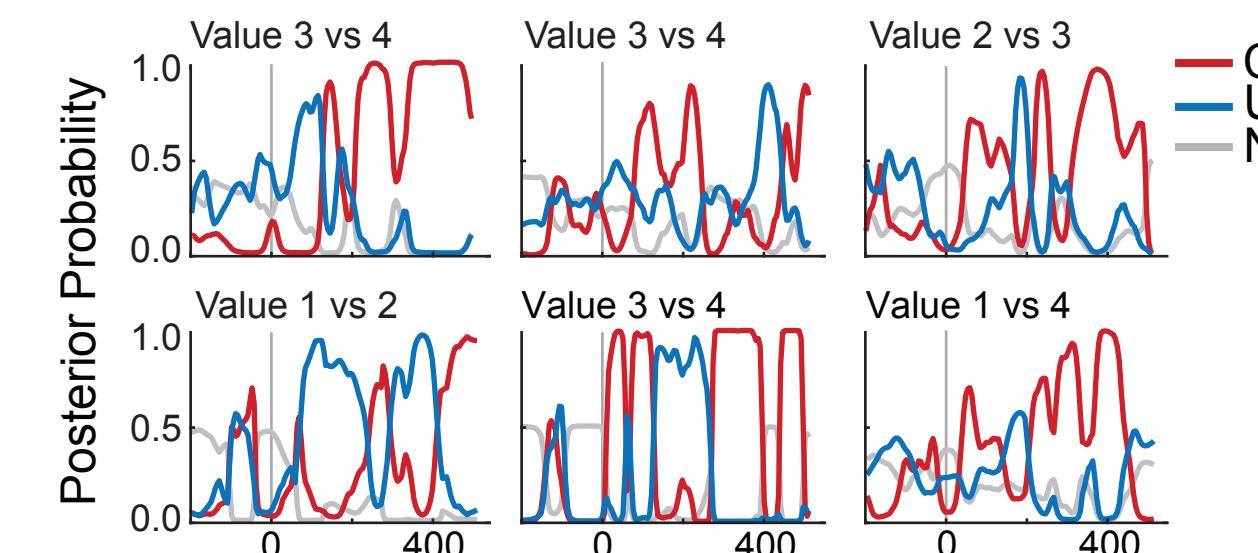
LDA Training data : Single picture trials
features averaged over 100-300ms after picture onset

Decoded data: Choice trials
features averaged over 20ms windows, stepped by 5ms

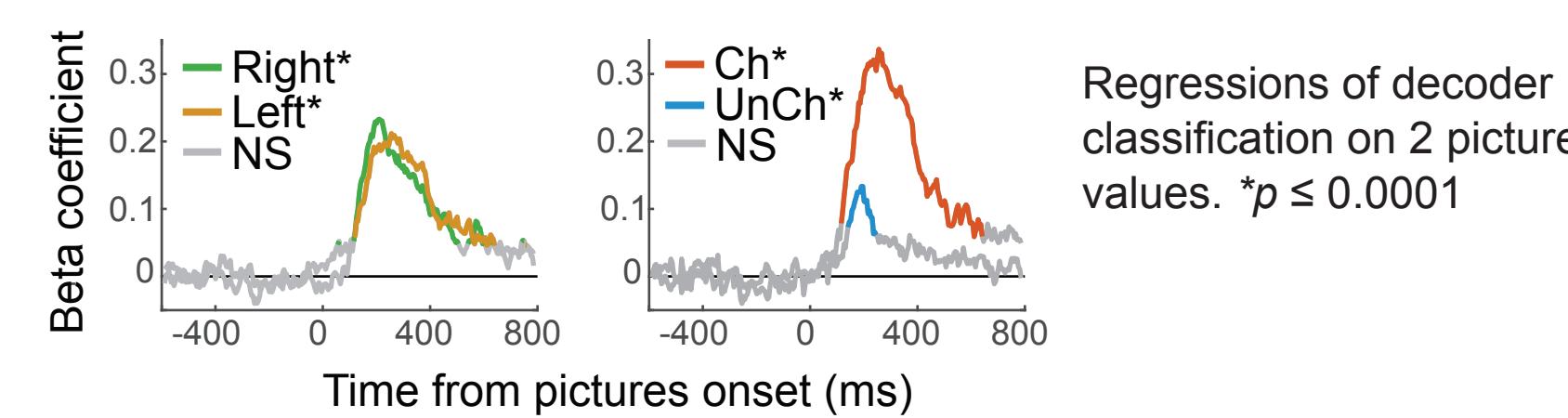
Neural Features: Neuron firing rates
Analytic amplitude of 6 LFP bands:
2-4 Hz 8-12 Hz 30-60 Hz
4-8 Hz 12-30 Hz 70-200 Hz

Decoding value during choices

Transient representations of chosen (Ch) and unchosen (UnCh) values were decoded from single choice trials

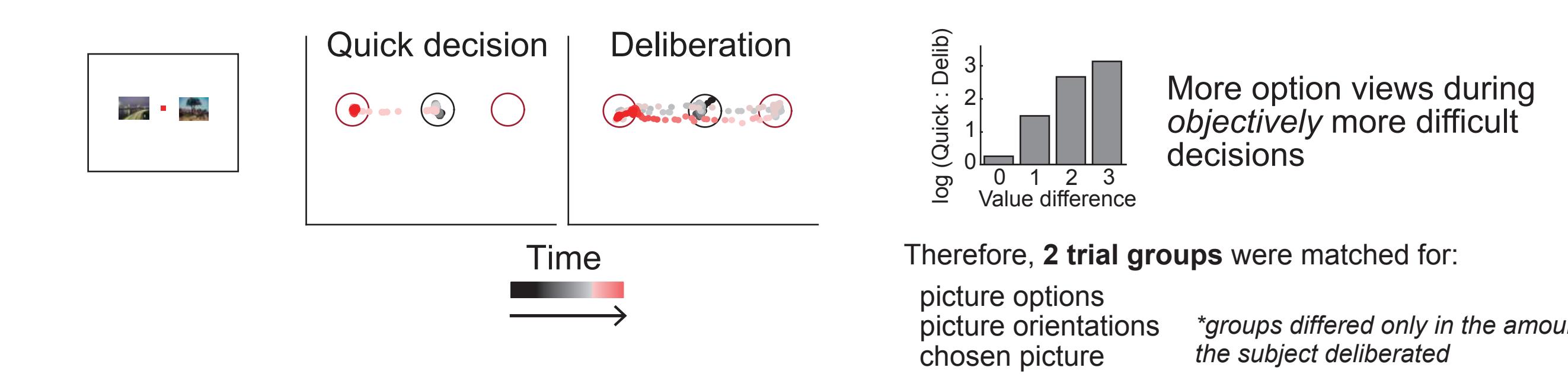


Values of pictures available on a given trial predict decoder classifications

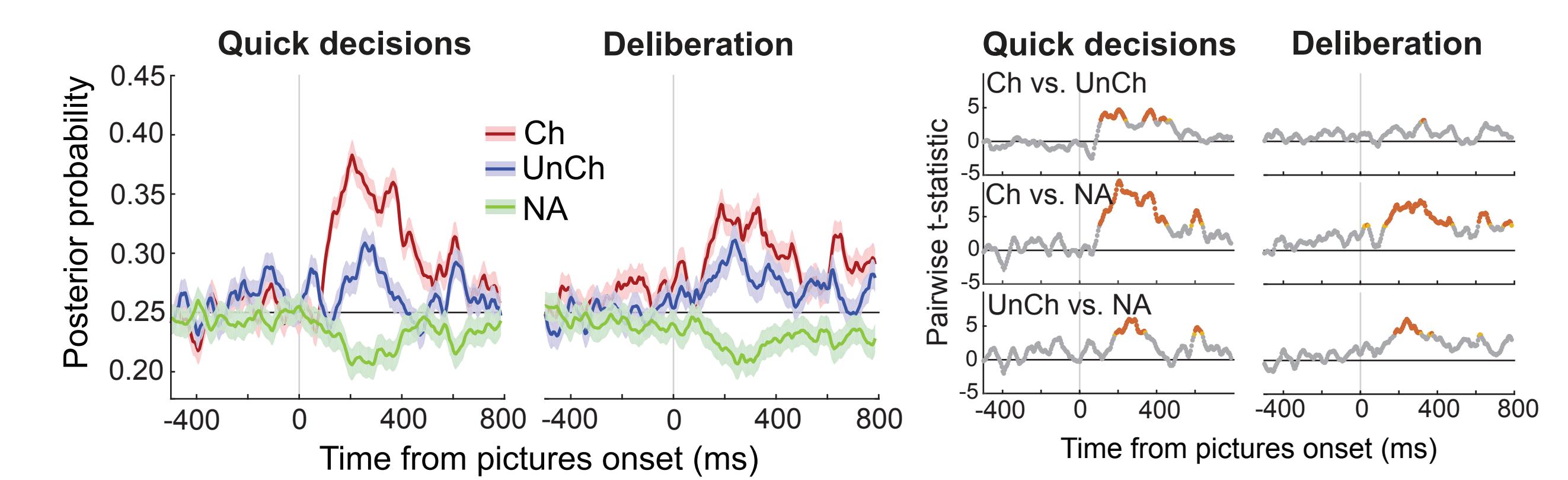


Decoded values predict choice deliberation

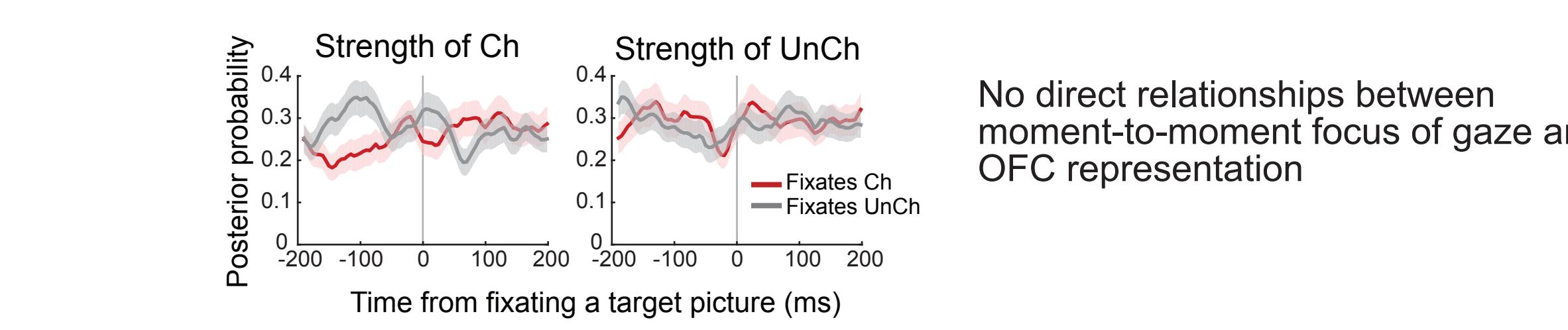
Eye movements reveal choice deliberation



Quick and deliberative decisions are represented differently in OFC

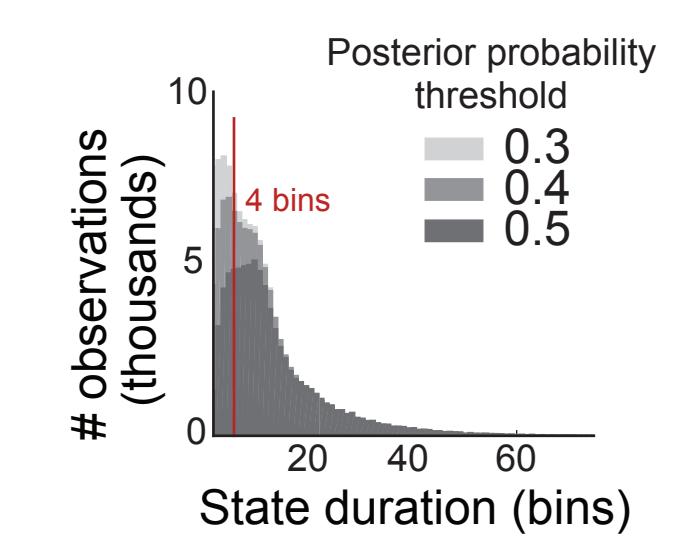


- When the subject makes quick decisions, chosen representations dominate.
- During deliberation the strength of chosen is reduced and is similar to unchosen.
- Deliberation does *not* lead to a loss of selectivity, both choice options are represented more than unavailable options.

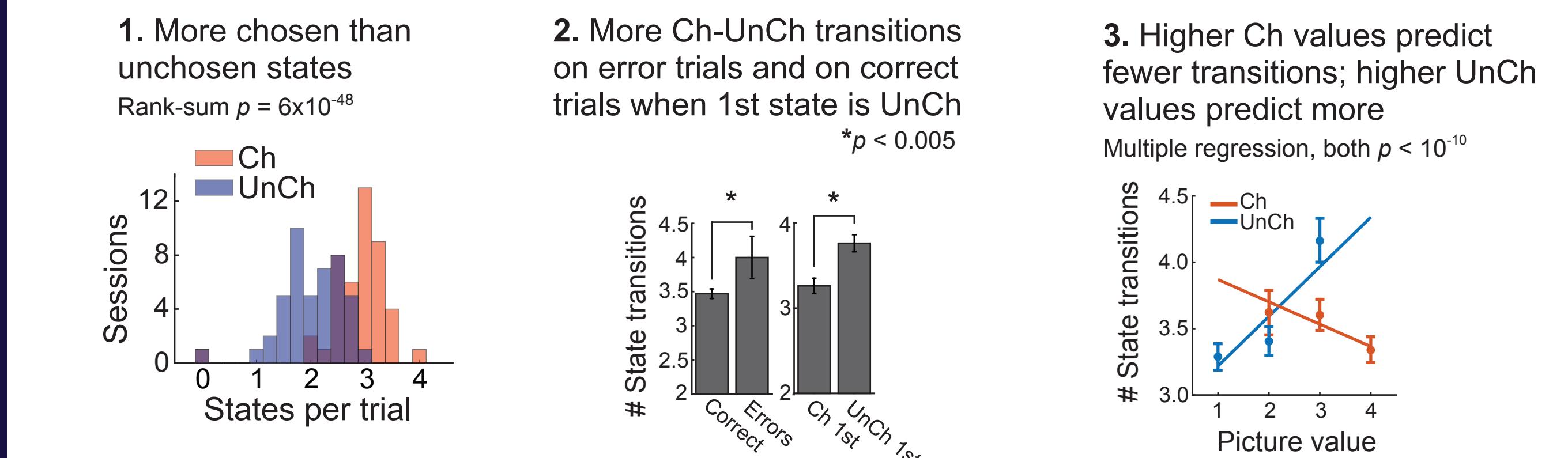


Choice decoding reveals stable neural states

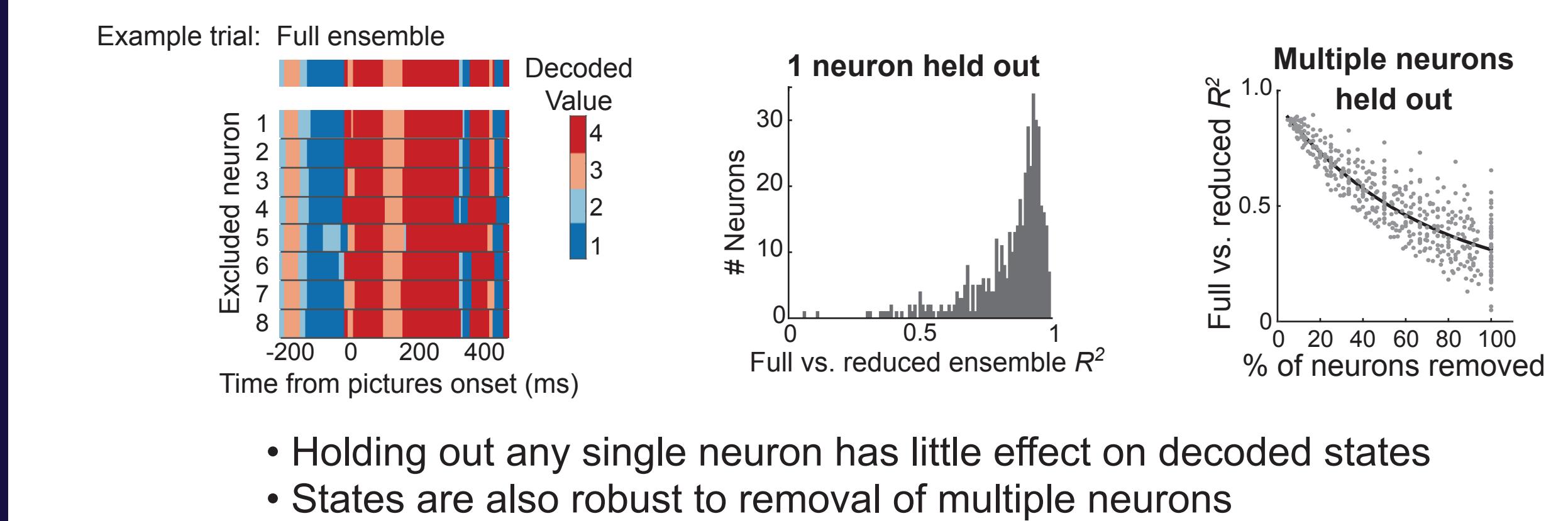
Stable states:
posterior probabilities ≥ 0.5
for ≥ 4 consecutive time bin



States reflect choice options and the decision:



State representations are distributed in OFC ensembles:

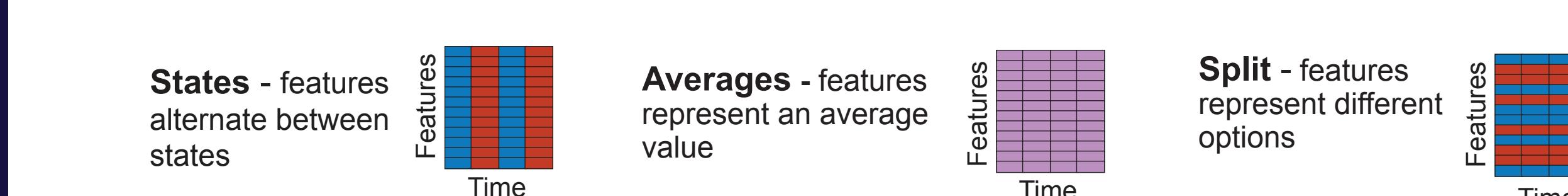


Would mixed signals yield artifactual states?

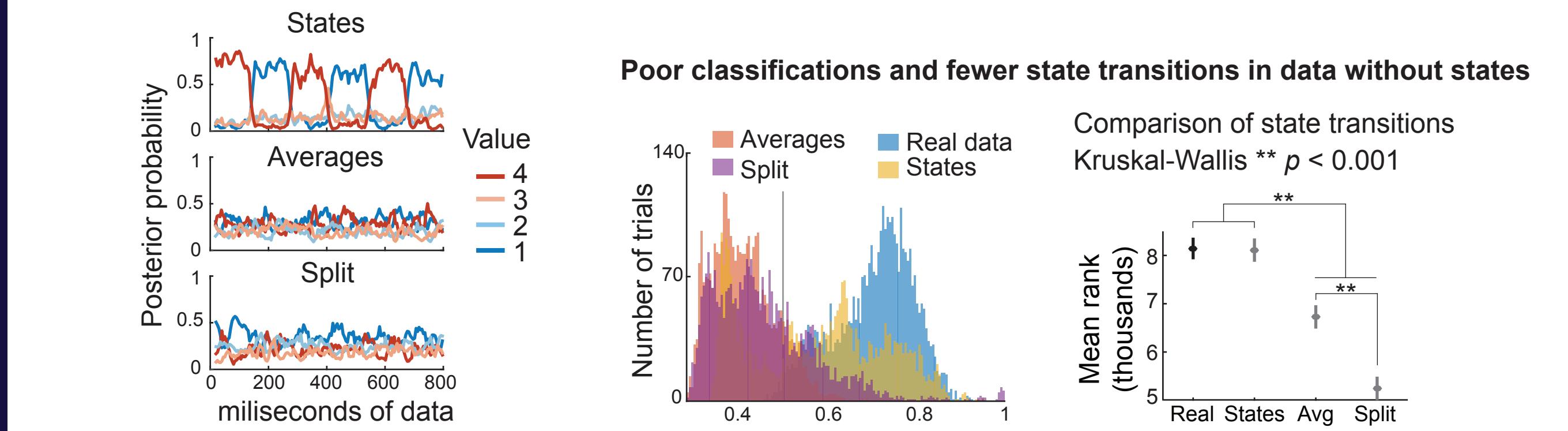
Synthetic data sets tested how known temporal structure is decoded by LDA

Data sets: Synthetic "trials" with and without alternating states, composed of neural data from single picture trials of each value

3 models were tested:



States were only recovered when present in the input features

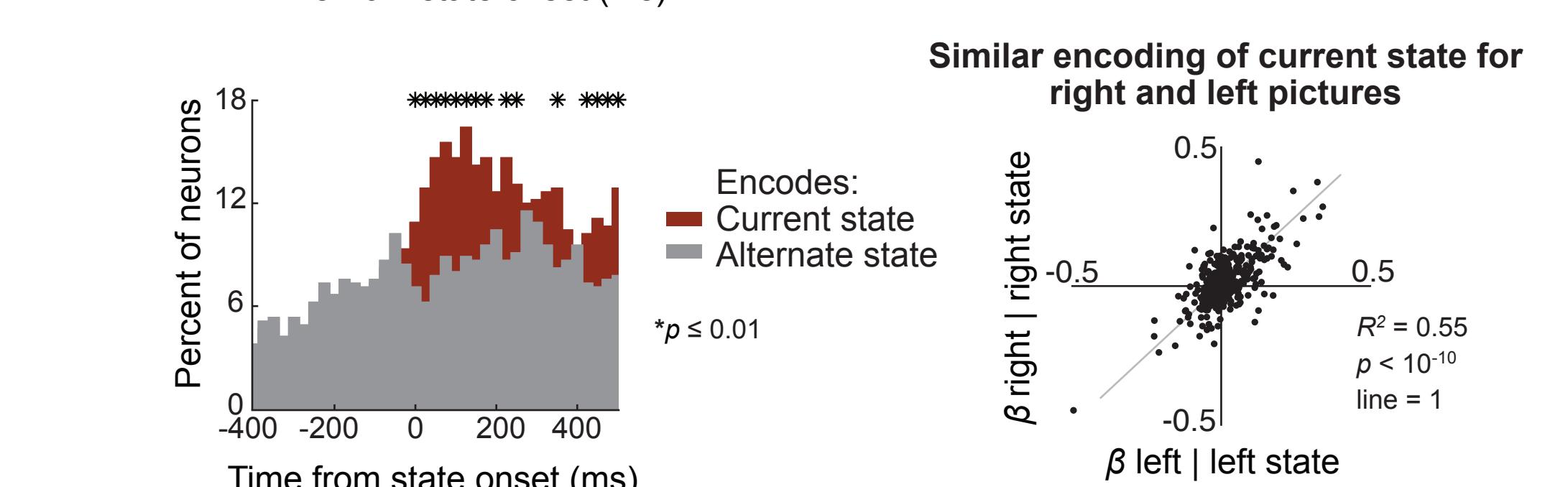


Single neurons encode current states

Analysis: 1 neuron held out, states decoded from the remaining ensemble, firing rates of held-out neuron re-aligned to state onsets
"Right / Left state" = decoded state corresponds to the picture value on screen right / left

- Example neuron:
 - When state = *right*, neuron encodes *right* picture value
 - When state = *left*, neuron encodes *left* picture value

This neuron's firing rate encodes the value of the current state.



- Firing rates of single neurons shift dynamically to encode multiple choice options.
- Neurons tend to encode the value of the current state over the value of the other (alternate) picture.

Conclusions

- Value-based decisions can include variability in choice behavior and neural activity, even when options and outcomes are identical.
- During value-based decisions, neural activity in OFC alternates between representations of two choice options with dynamics that correlate with the options presented and with choice behavior.
- These representations consist of discrete neural states, corresponding to the value of each choice option. The states are a feature of a distributed network, and can predict firing rates of a held-out neuron.
- The dynamic representation of choice options in OFC may constitute a mechanism supporting value comparison or prediction during subjective decisions.

References

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Poster can be downloaded at erich001.github.io/areadne2016.pdf
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