Do glitches in the OFC neural code explain irrational choices? A neuro-computational approach to value synthesis.

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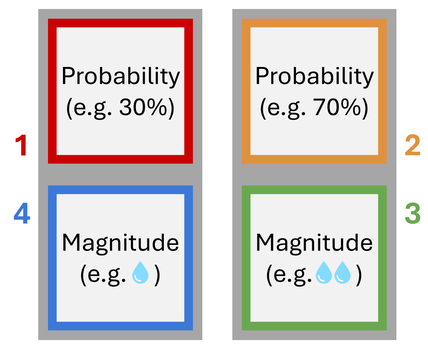
Abstract

We trained recurrent neural networks to solve different computational problems for value-based decision-making, either optimally or following irrational behaviors observed in monkeys. We found that several models spontaneously develop neural characteristics matching observations in the orbitofrontal cortex. Moreover, the irrational models appeared to be more energy efficient and more robust to lesions compared to the optimal ones.

1. Task design

Single-unit electrophysiological recordings were gathered by **Hunt et al. (2018)** in the orbitofrontal cortex (OFC) of two macaque monkeys during a *sequential binary decision task*.

The value of each option is synthesized from the integration of its attributes (*probability* and *magnitude* of reward).

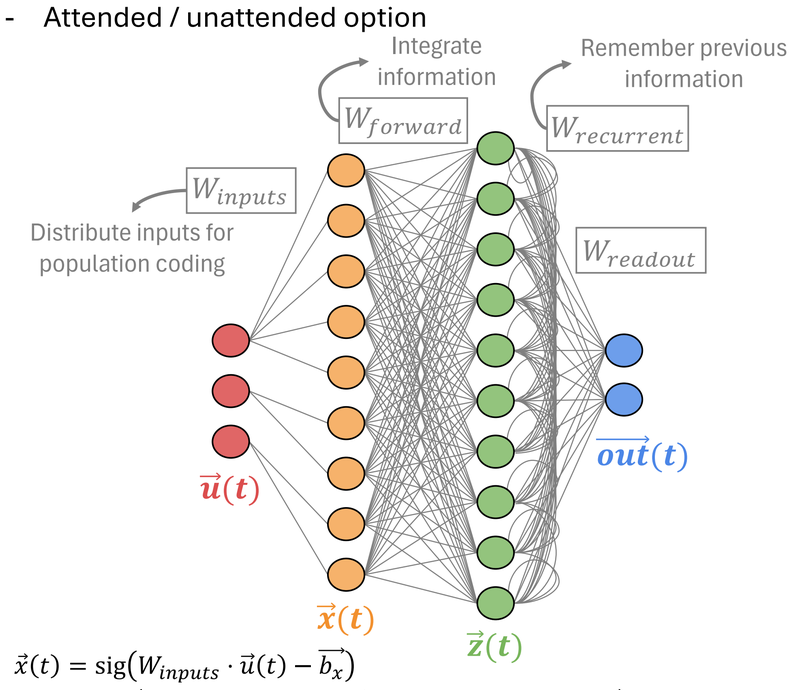


Task layout with example decision and sampling order.

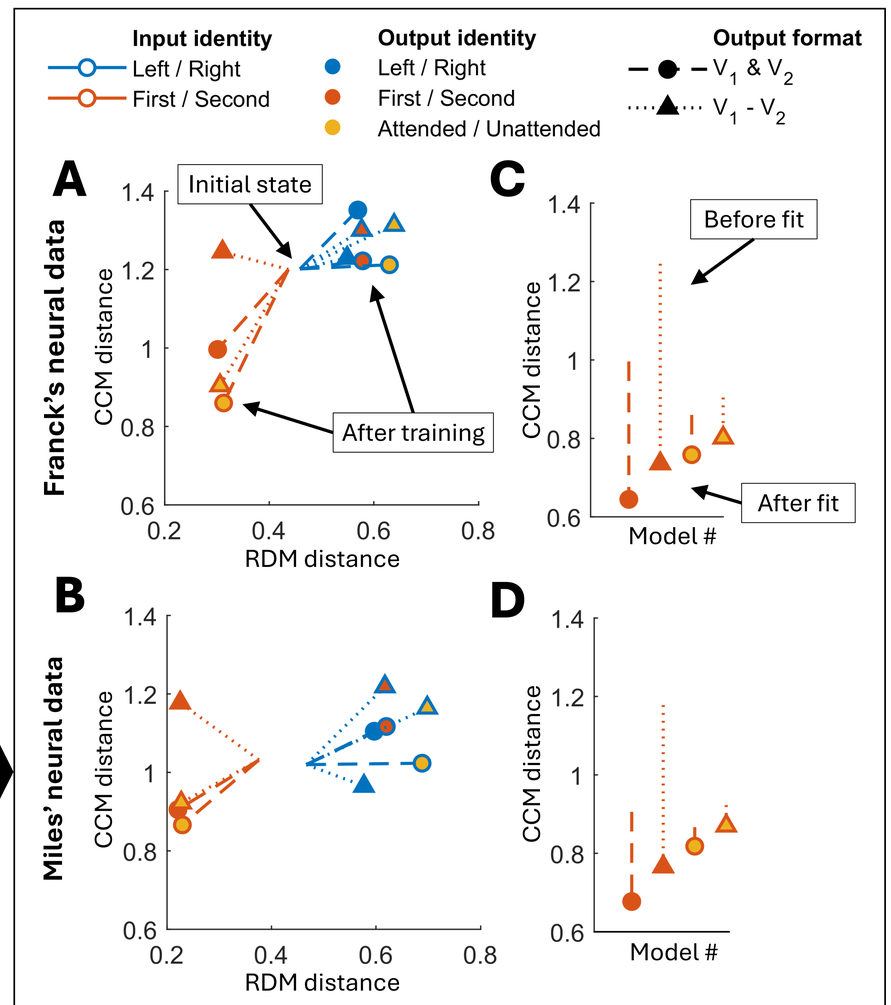
2. Recurrent Neural Network (RNN)

We build models which integrate the **information just acquired** to estimate either the **value of both options** or their **difference**. We vary the framework they use in input and output:

- Left / right option
- First / second option
- Attended / unattended option



$$\vec{x}(t) = \mathrm{sig}\left(W_{inputs} \cdot \vec{u}(t) - \overrightarrow{b_x}\right)$$
$$\vec{z}(t) = \mathrm{sig}\left(W_{forward} \cdot \vec{x}(t) - \overrightarrow{b_z} + W_{recurrent} \cdot \vec{z}(t-1)\right)$$
$$\overrightarrow{out}(t) = W_{readout} \cdot \vec{z}(t)$$



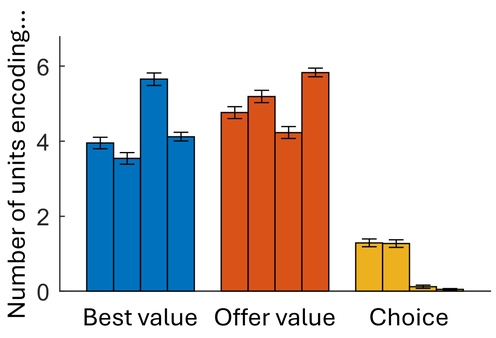
3. Several models develop a representational geometry close to that of the OFC through training and fitting

A-B) Models initially have random weights and are trained to perform their task optimally (i.e. maximize reward amount).

C-D) Models initially perform their task optimally and are fitted to the behavior of the monkey (i.e. predict monkey choices) by distorting their recurrent connections.

4. The candidate models develop *best value* cells, *offer value* cells and *choice* cells through training

See Padoa-Schioppa & Assad (2006).

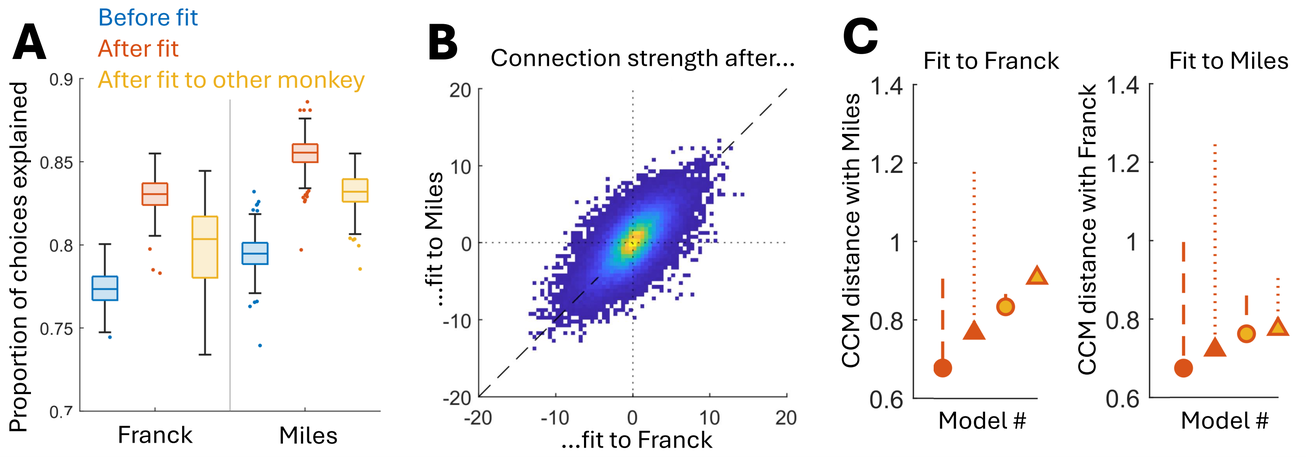


6. The models capture irrational features common to both monkeys

A) Irrational choices learned from one monkey generalize to the other one.

B) The connection distortions are similar after fitting models on both monkeys.

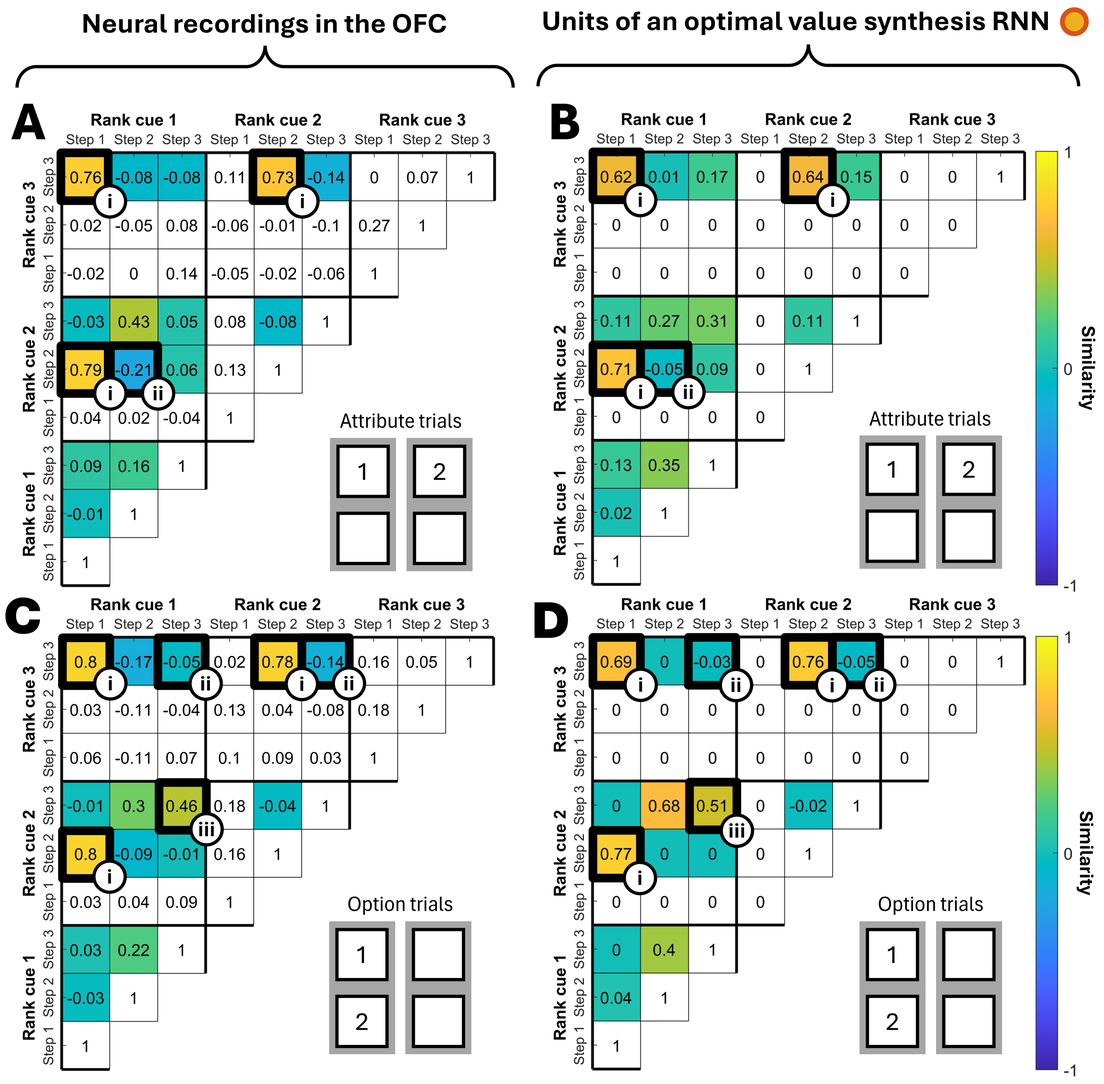
C) Models fitted to the behavior of one monkey also get closer to the representational geometry of the other monkey's OFC.



5. Value synthesis models can reproduce key representational geometry features from the OFC

A-D) How similarly does the neural population encode the rank of cue A during a period T_A, and the rank of cue B during a period T_B ?

i) Stable encoding of current cue rank
ii) Relative encoding of option values
iii) Attribute integration to build option value



7. Irrational models are more energy efficient and more robust to lesions compared to optimal models

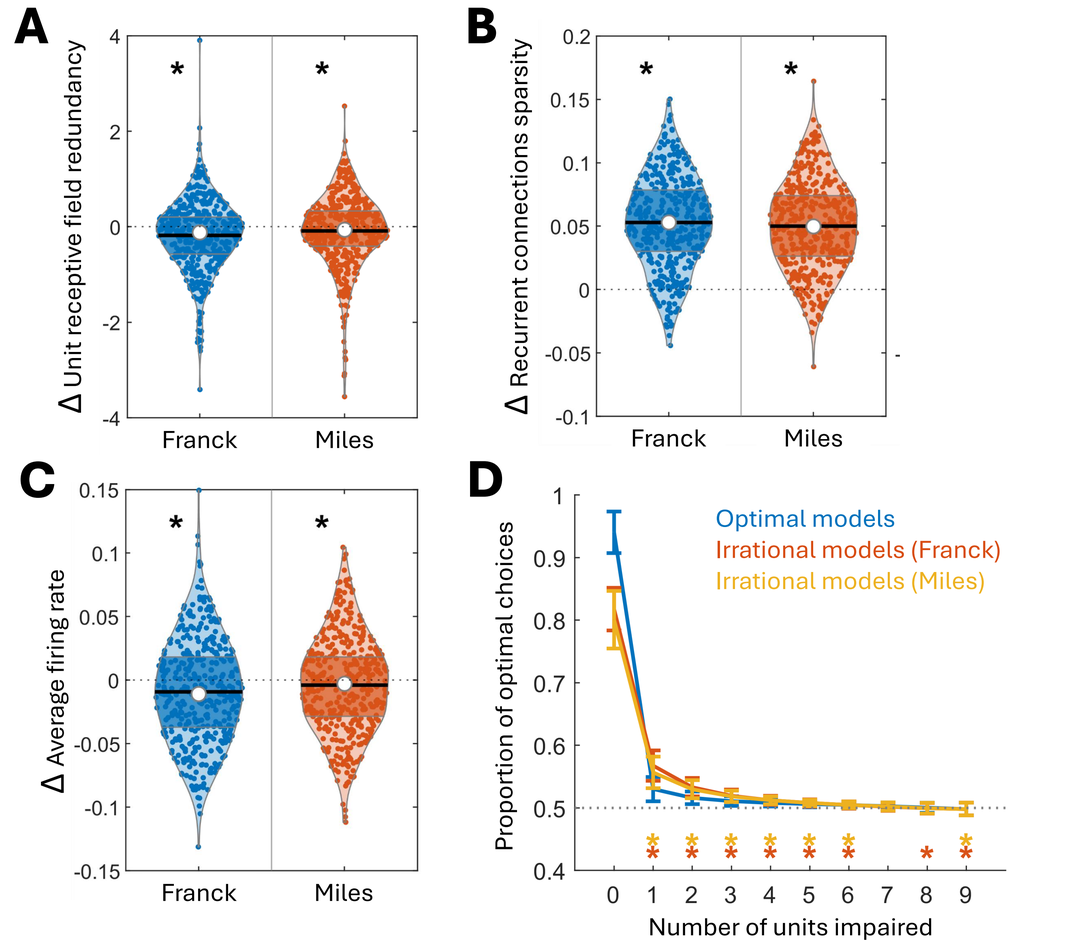
Therefore, non-optimal decisions might actually result from constraints on the neural code of the underlying decision system.

A) Irrational models activate fewer units simultaneously than optimal models.

B) Irrational models have more sparse recurrent connections.

C) The units of the irrational models fire less on average.

D) Lesioned irrational models make better decisions compared to lesioned optimal models.



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