Feedback Activity In Perceptual Decision Task

By: Aiqing Qiu, Yijin Shan, Xinyi, Zhiyu Tian, Yiheng Qiu, Tien-Anh Vu

Pod Archaeopteryx kolatt / Cheesy Jerry

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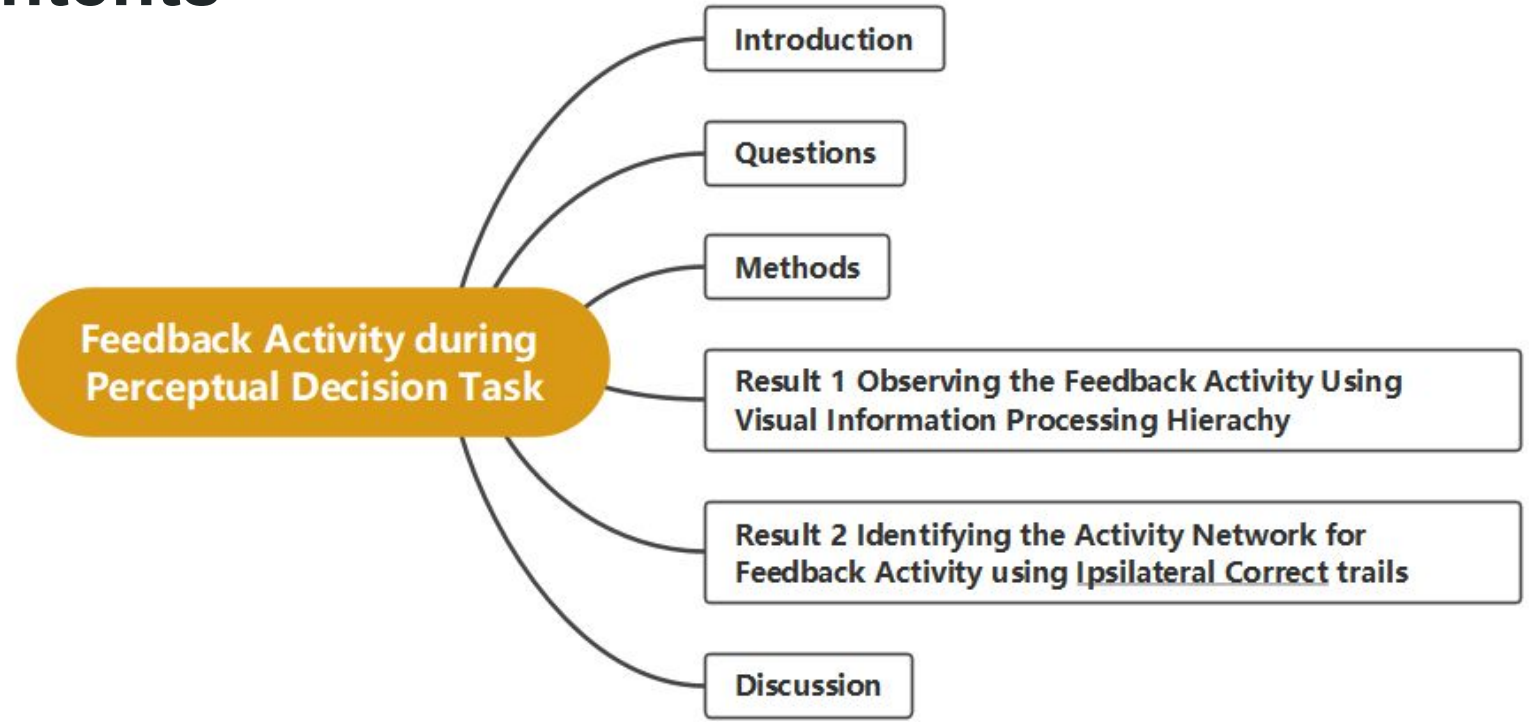
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Introduction

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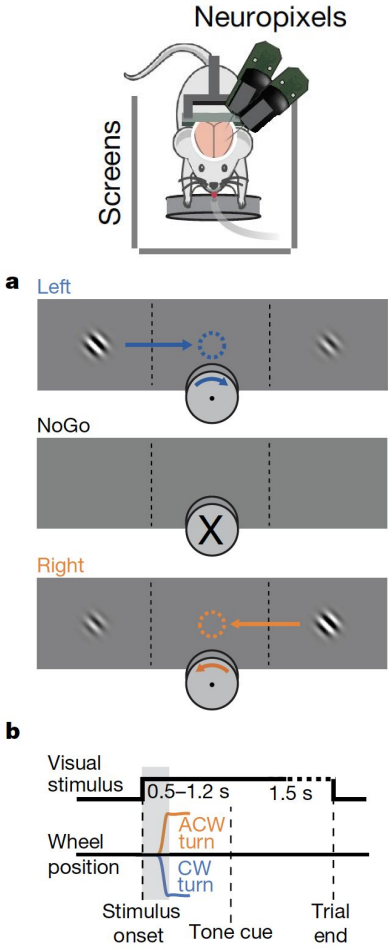
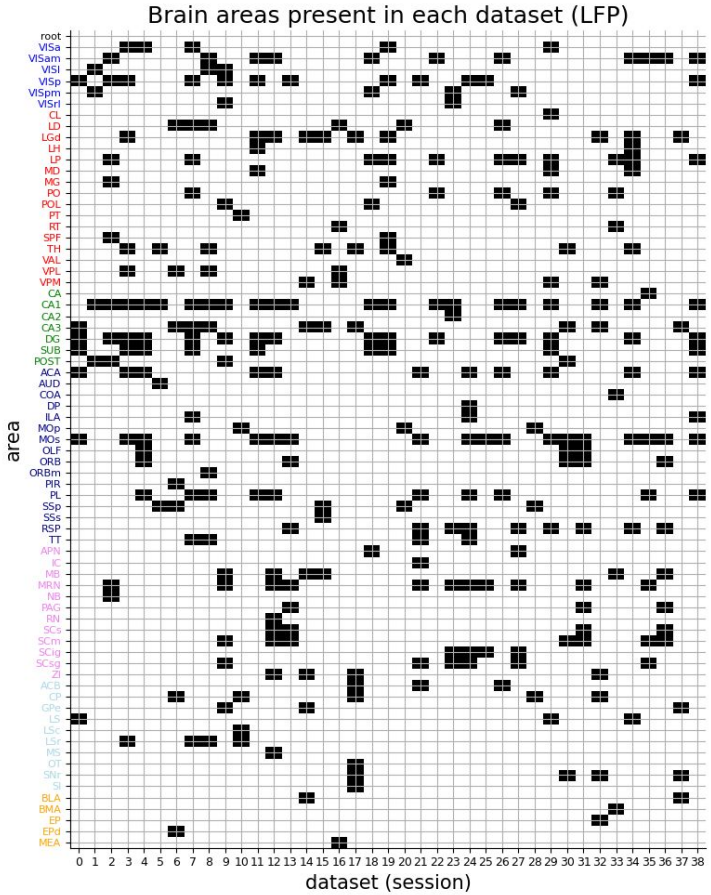




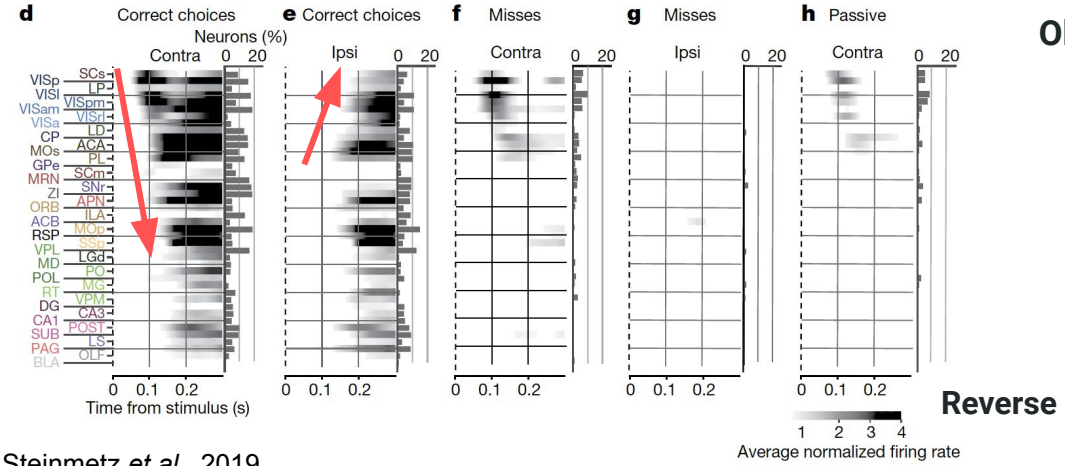
dataset source: Steinmetz et al., Nature, 2019

Set-up: 2/3 Neuropixel probes recorded left hemisphere only + mice performing task

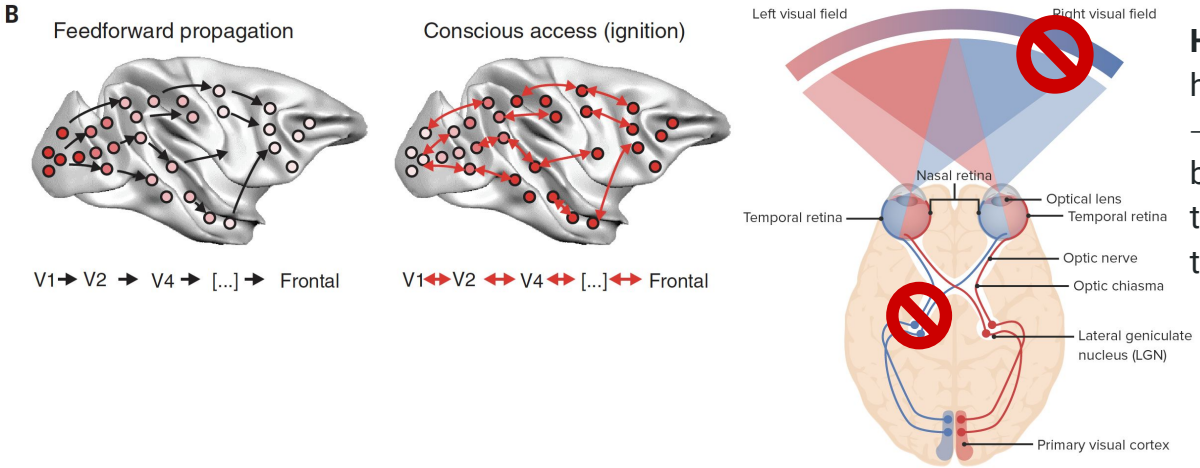
Visual Discrimination task: stimulus onset → response/action → +ve/-ve reward

39 sessions (>200 trials each) from 10 mice + ~30,000 neurons in 42 brain regions

Data over time course: LFP + Spiking of individual neurons



Steinmetz *et al.*, 2019



Observations & Motivations:

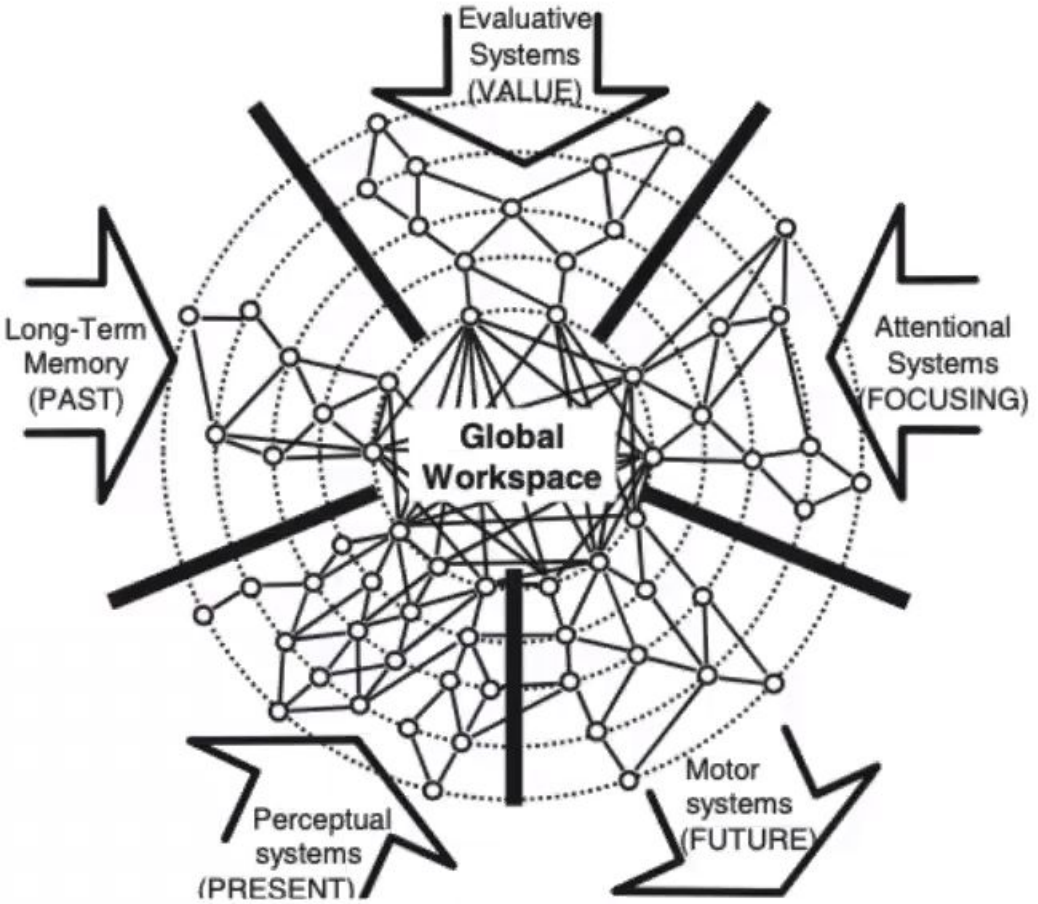
- Correct (attended) + contra- vs. ipsilateral trials: Opposite neural trends.
- Miss (unattended) + contra- vs. ipsilateral trials: Activity in contra; none in ipsilateral stimuli.
- Little or no interhemispheric communication in miss + ipsilateral trials

"Why does ipsilateral stimulus activity only emerge in correct trials?"

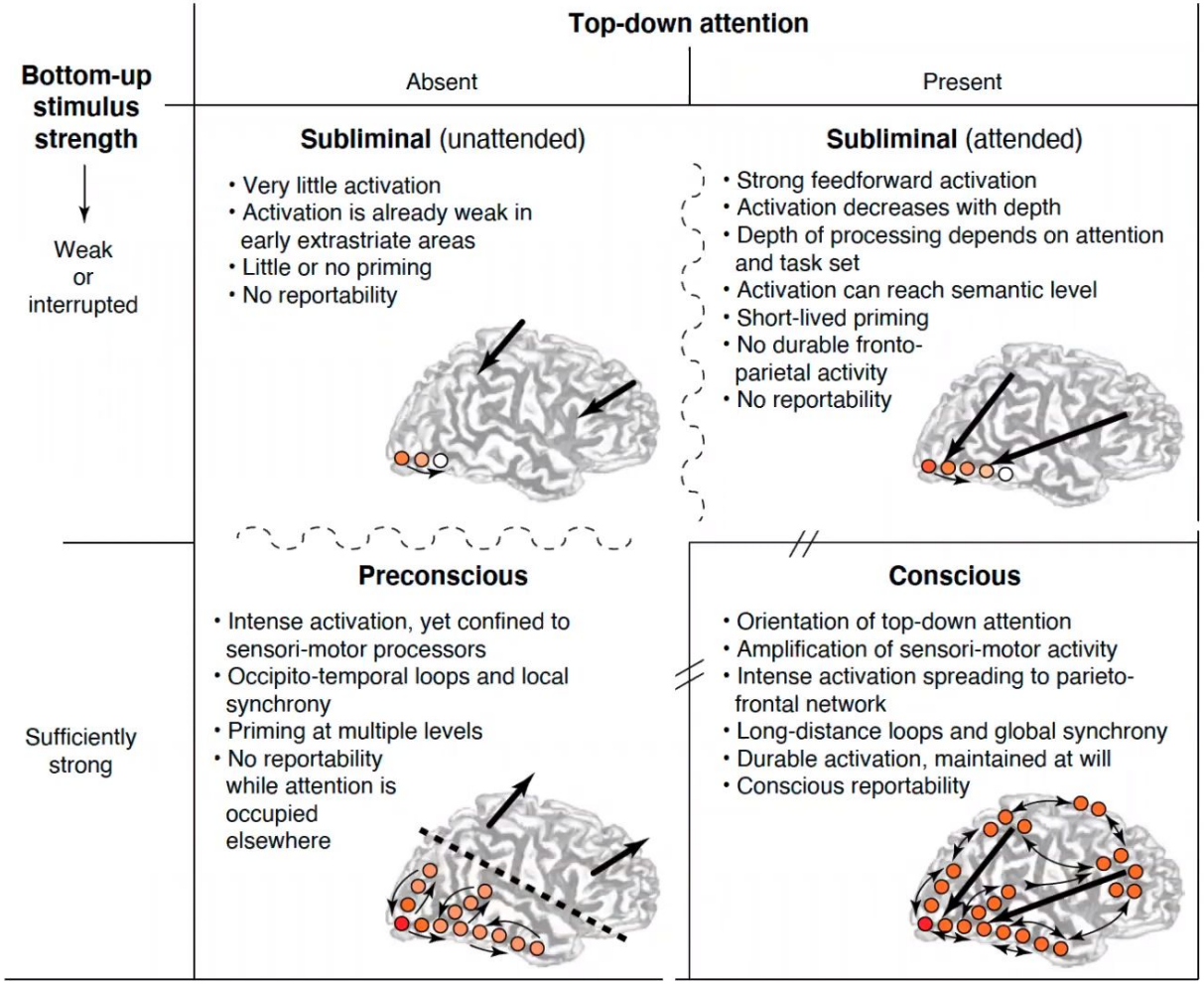
Hypothesis: Feedback (attention) from higher-order cognitive cortex → Global neuronal workspace (GNW) → broadcast to other cortices (global ignition) to motor cortex: correct movements to left hemisphere: neural activity

Objective: Investigate feedbacks as the reverse neural propagation from higher-order cognitive to sensory input regions (in a stricter setting).

Global workspace hypothesis



Dehaene *et al.*, 1998



GNWT:

Attentional amplification is necessary for conscious access.

Dehaene 2006 TICS

Neural basis of attention

Questions

Is there evidence of a reverse hierarchical pattern in weak activity indicative of feedback?

- In the visual cortex (positive control, feedforward activity)?
- From higher-order cognitive to sensory input regions (feedback activity network)?

Methods

1 - In the visual cortex (positive control)?

–> Latency Analysis

–> Kendall Rank Correlation Test

2 - From higher-order cognitive to sensory input regions

–> Pairwise directionality score (Cross Correlation)

–> Pathway Construction (DFS)

Result 1
Observing Feedback Activity

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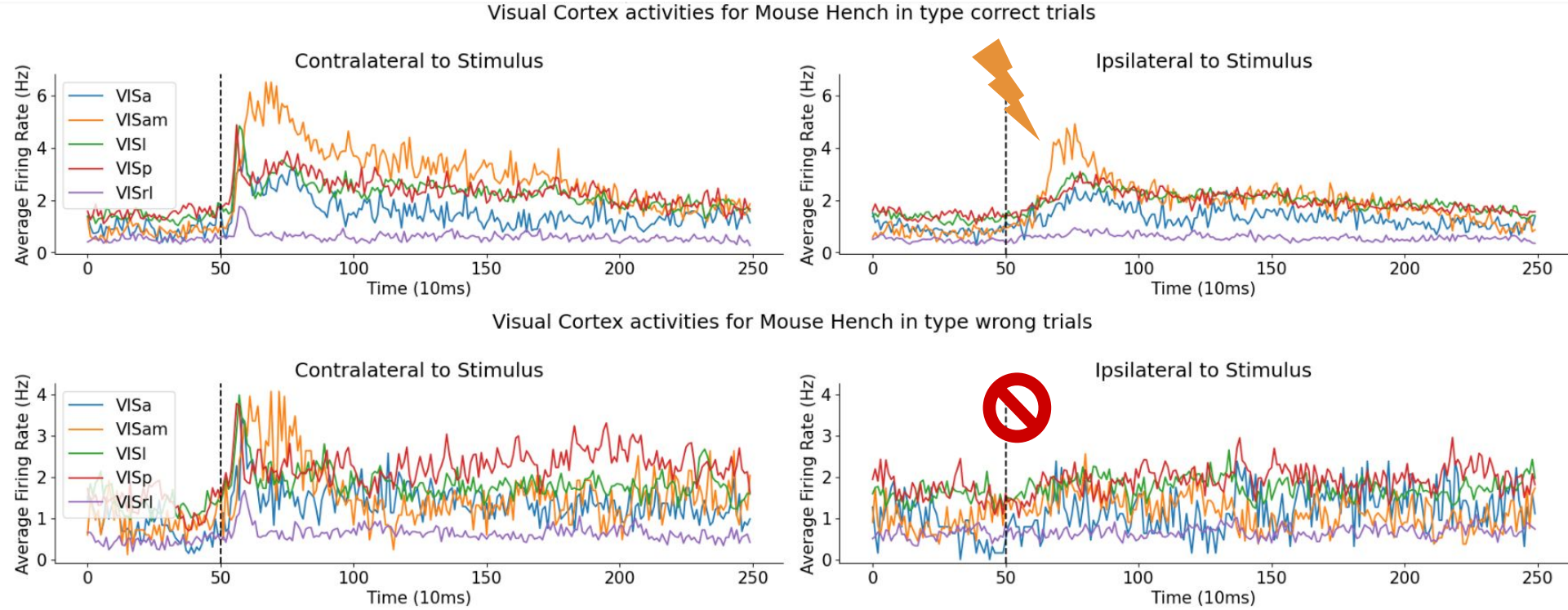
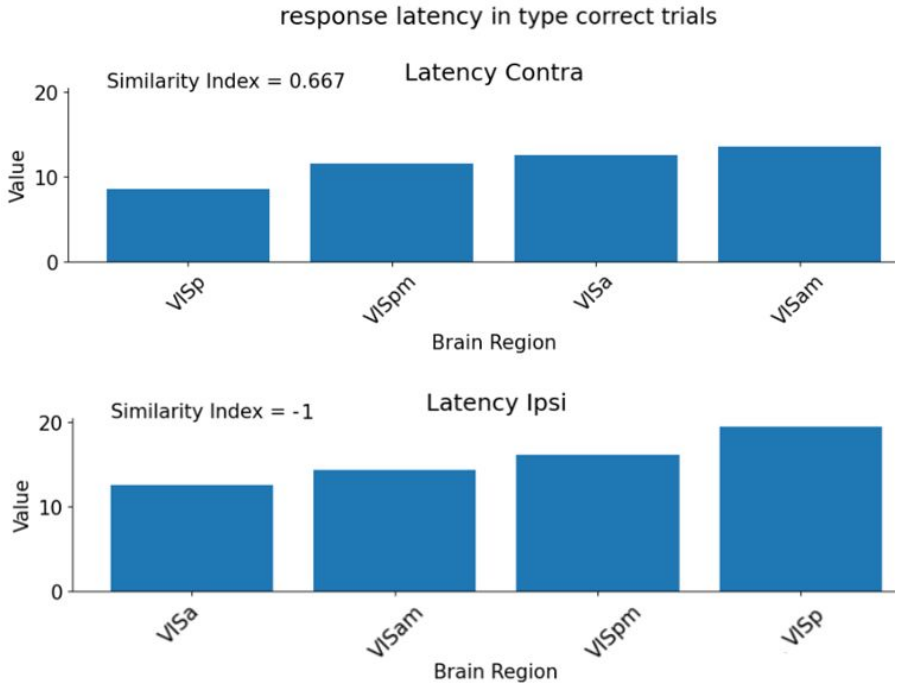
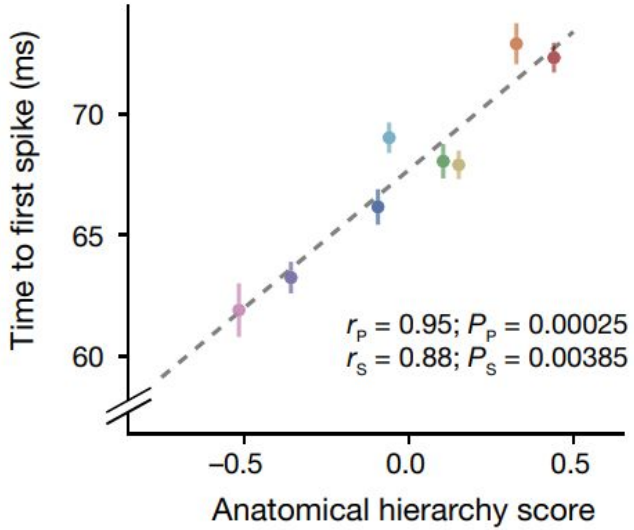
Example traces for Mouse Hench



Latency Ranking & Rank Correlation

Proved Hierarchy: VISp -> VISl -> VISrl -> VISal -> VISpm -> VISam (Siegle et al. 2021)





Siegle, et. al, Koch, C. (2021). Survey of spiking in the mouse visual system reveals functional hierarchy. Nature, 592(7852), 86-92.

elements related
to global ignition

Result 2
Identifying Feedback Activity Networks

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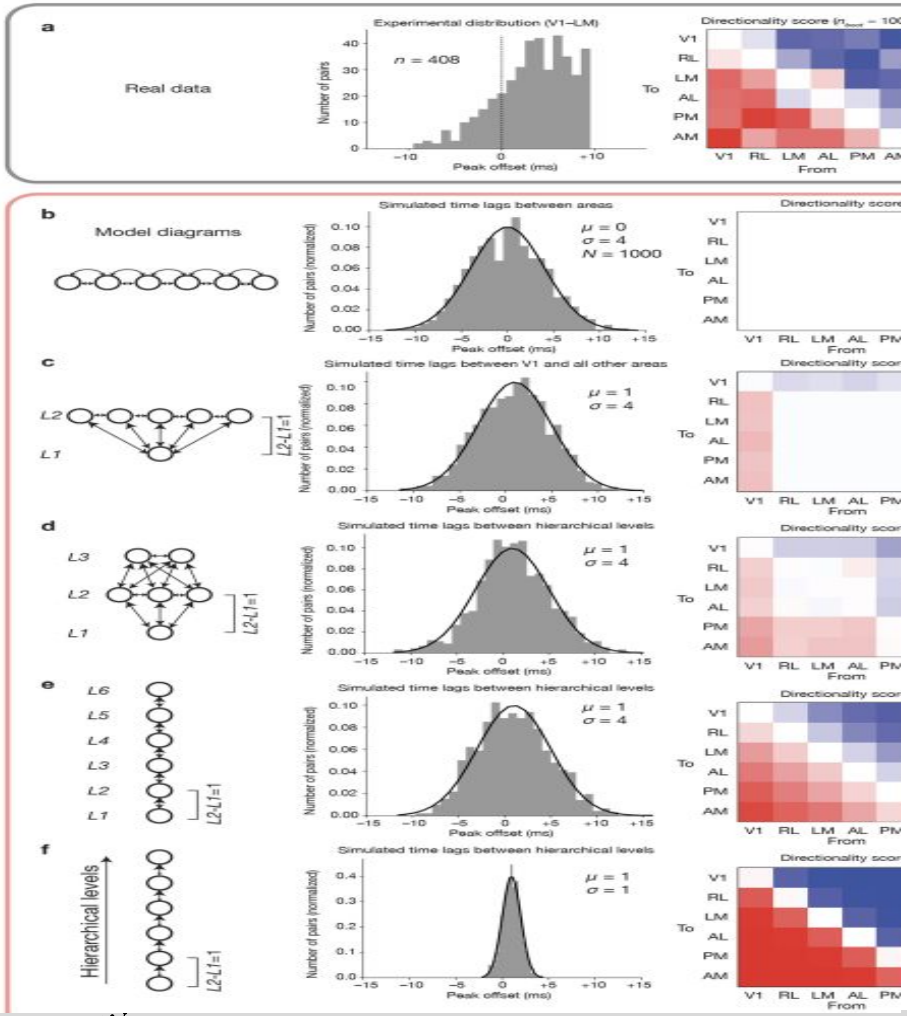
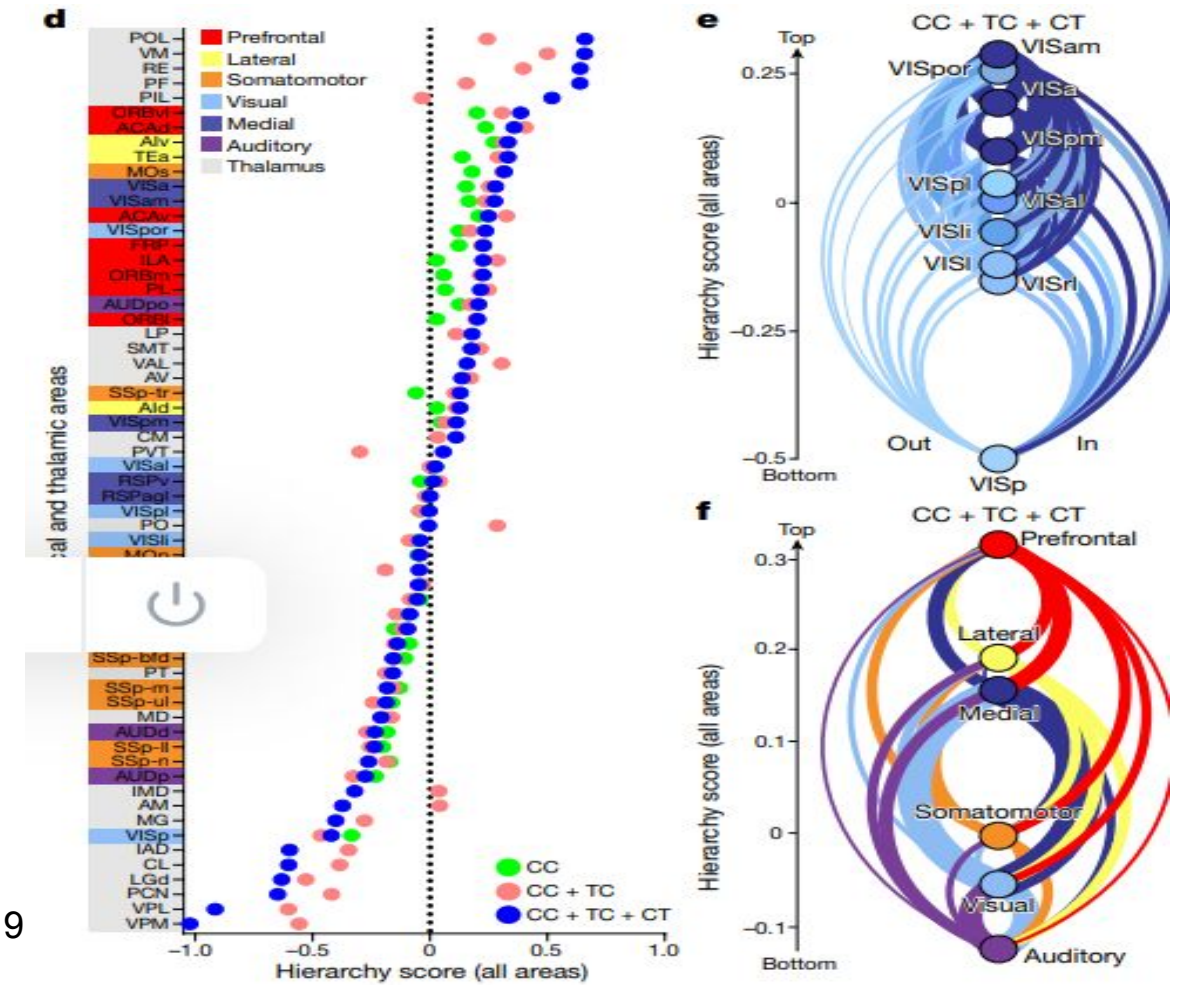
Network modeling for pathways



Siegle *et al.*, 2021

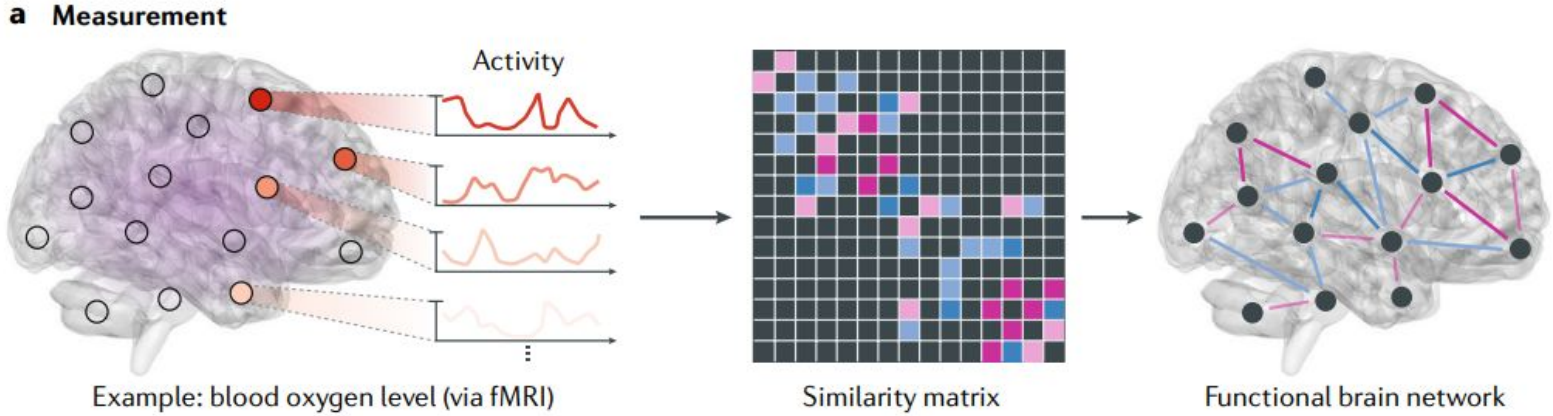
A hierarchical organization of cortical and thalamic areas



Haris *et al.*, 2019

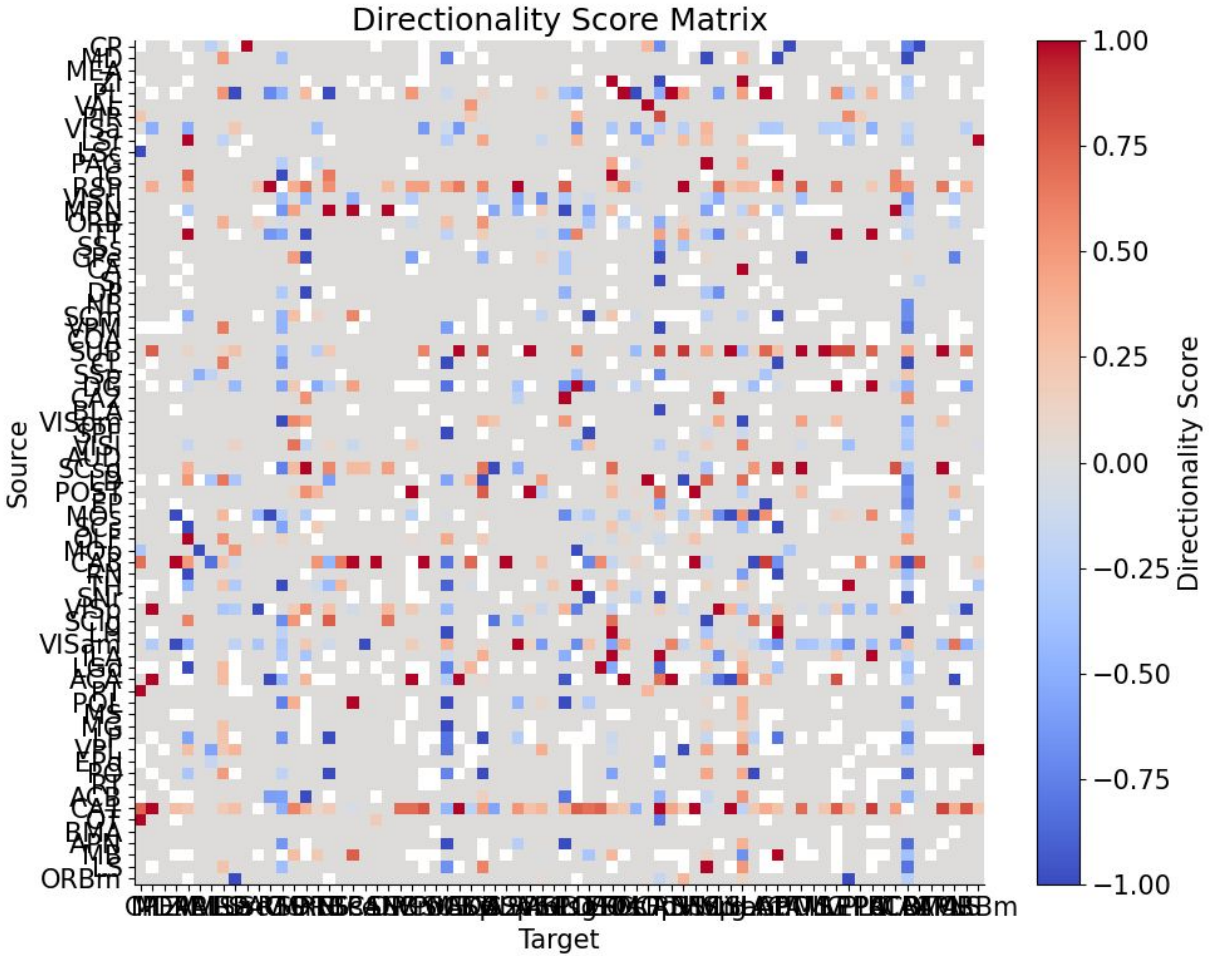
Pathway construction

- Pairwise brain area direction: DS (Directionality score) matrix
- Align directions to pathways: DFS (Depth first search) algorithm
- Model network types: CCG (Cross-correlogram) peak distribution + DS matrix

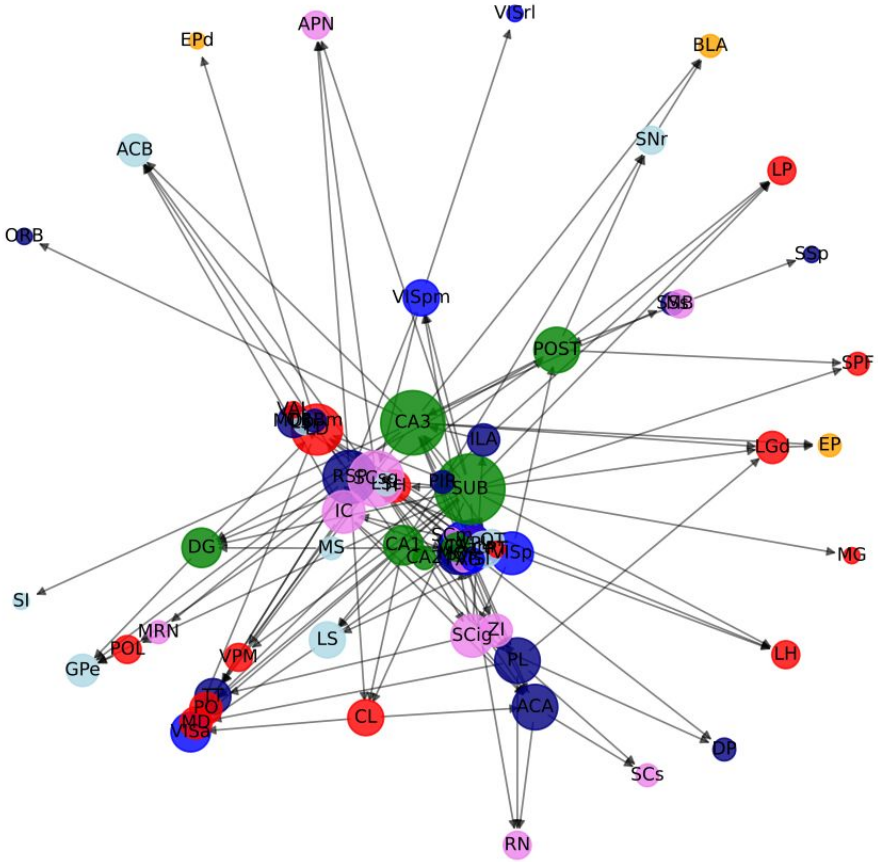


Lynn *et al.*, 2019

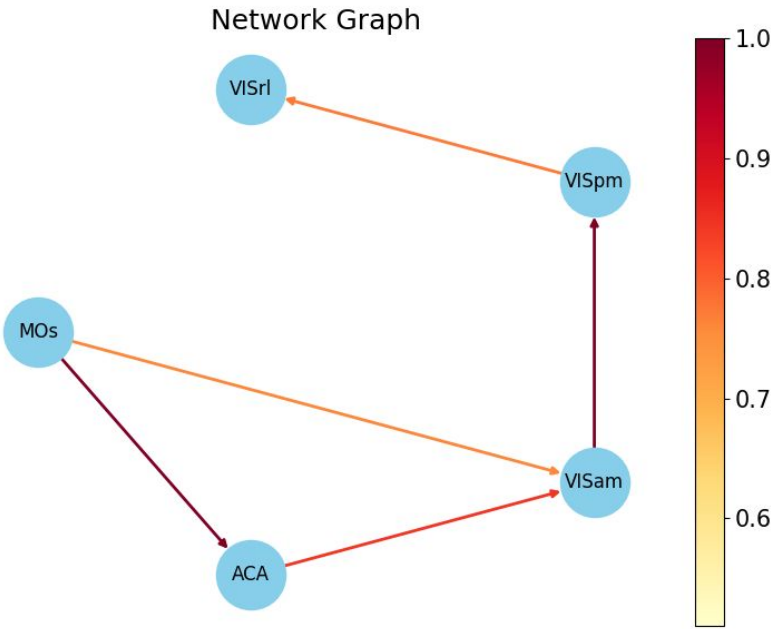
Sparsity of pairwise directions in population

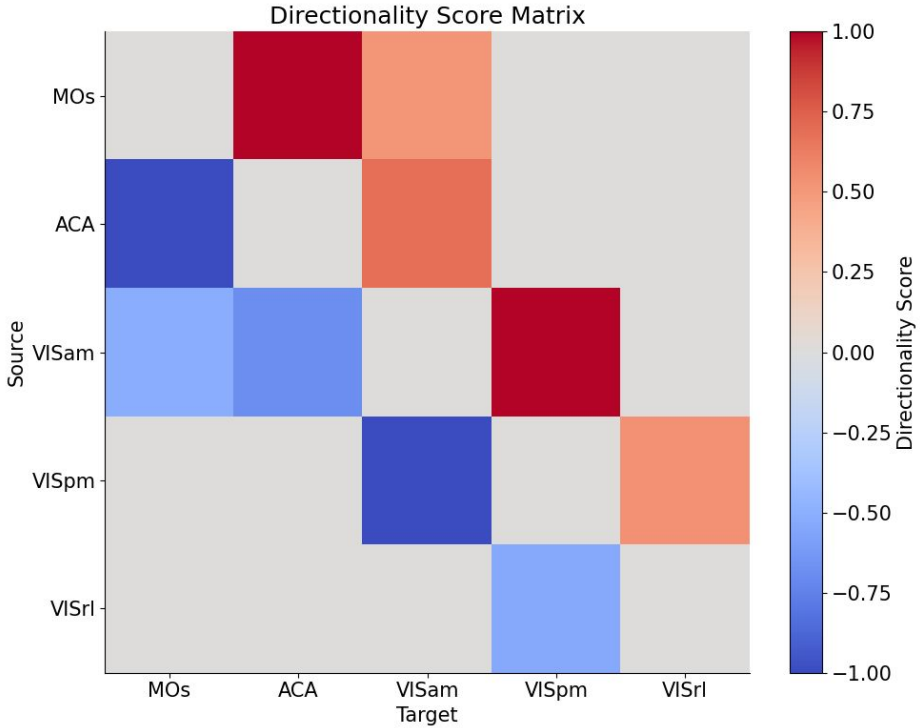


Network of pathways related to feedback

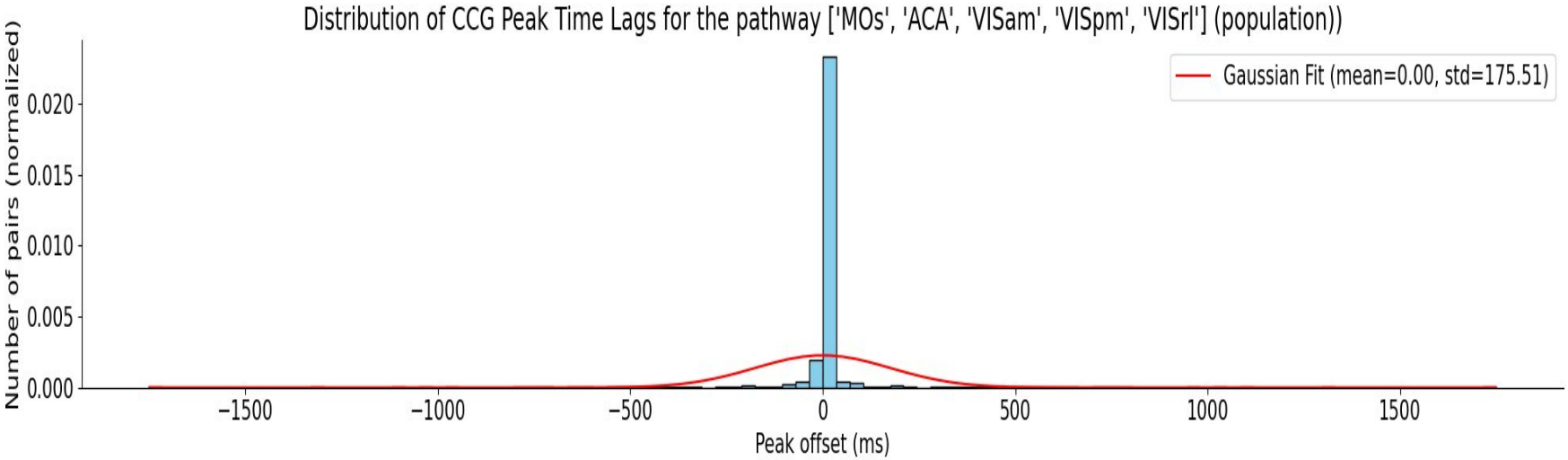


Pathway MOs -> ACA -> VISam -> VISpm -> VISrl

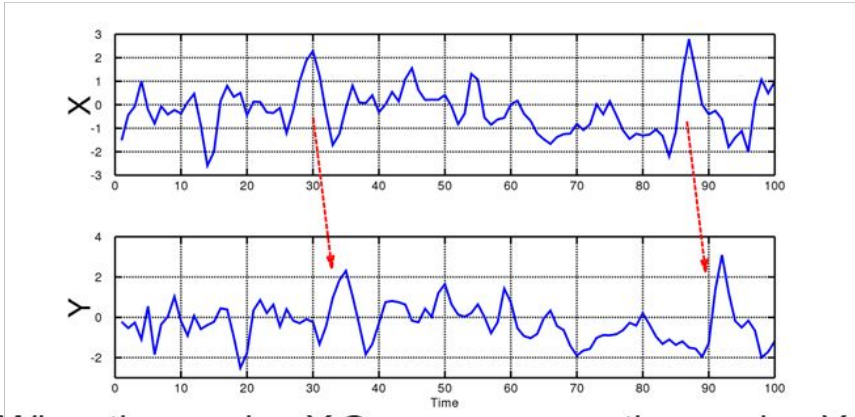




CCG distribution MO->ACA->VISam->VISpm->VISrl



Granger Causality Analysis



When time series *X* Granger-causes time series *Y*, the patterns in *X* are approximately repeated in *Y* after some time lag (two examples are indicated with arrows). Thus, past values of *X* can be used for the prediction of future values of *Y*.(Cr. Wikipedia)

visual cortex thalamus
hippocampal non-visual
midbrain basal-ganglia
cortical-subplate

1.Cori

MOs -> VISp: 11.32%

SUB -> VISp: 16.00%

2.Forssmann

CA1-> VISa: 12.31%

3.Hench

4.Lederberg

LGd -> VISam: 34.38%

ACA -> VISam: 40.21%

ACA -> MOs: 31.37%

MOs -> VISam: 18.75%

MOs -> VISam: 18.75%

MS -> VISam: 21.88%

PL -> VISam: 32.99%

5.Moniz

RSP -> VISp: 16.79%

CA1 -> VISrl: 25.00%

6.Radnitz

7.Richards

8.Tatum

TH -> VISam: 12.26%

LS -> VISam: 11.21%

MOs -> VISam: 13.21%

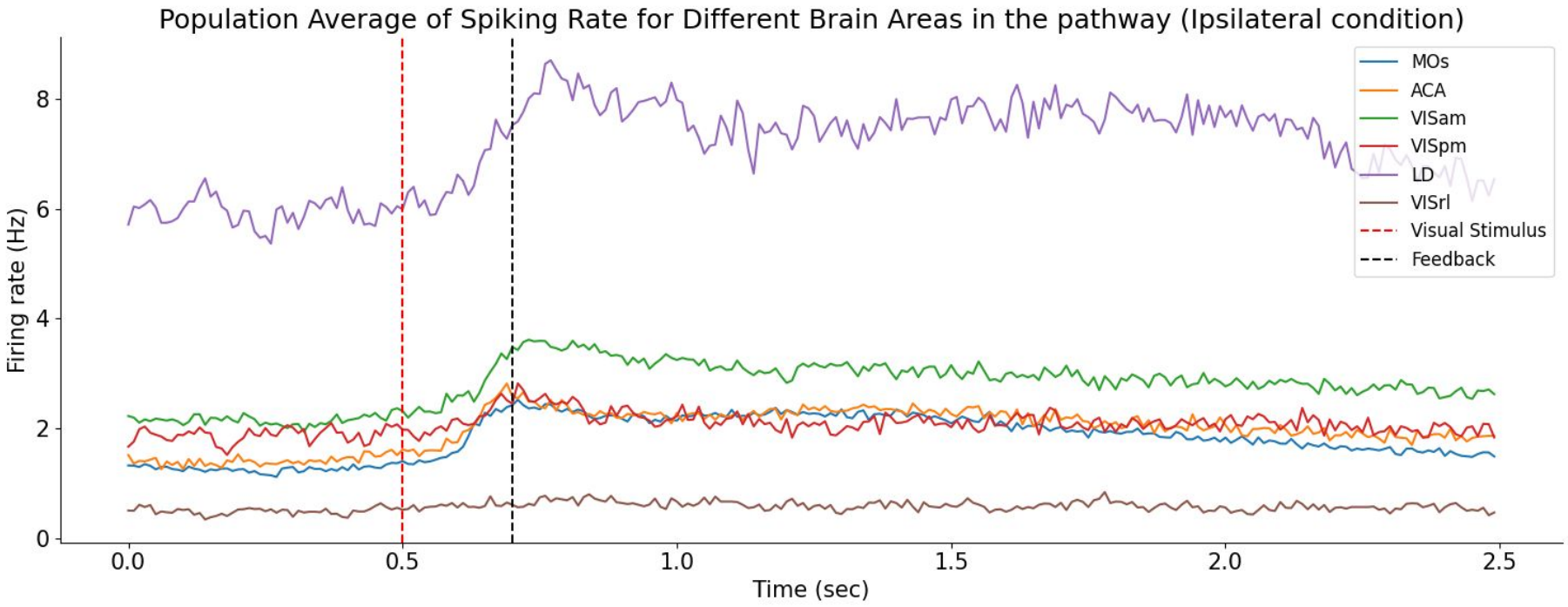
MOs -> VISam: 28.57%

ORB -> VISam: 11.63%

9.Theiler

VISp -> VISam: 12.00%

Spiking rate of some areas in the feedback



Discussion

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Limitation

- Limitation in the dataset: Temporal Resolution
- Limitation in the current literature landscape: lots of interareal connections have not been investigated, so the feedback-driven pathways could not be compared and validated.

- **Just** find some evidence **that possibly** supports feedback connections

  BUT still not prove the existence of a feedback connection

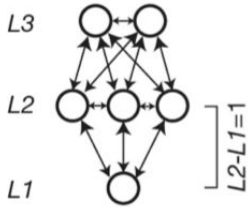
  i) When does the feedback **actually arrive** after visual stimuli?

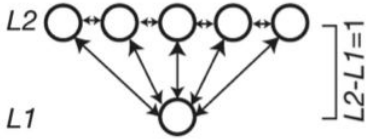
  i) What are the **true Neuronal Correlates of Consciousness (NCC)** for feedback connection in this visual decision task?

  ii) What are the **significant differences** of feedback-driven NCC between **conscious and unconscious** neural state in the visual decision task?

- Several possible analyses have not been done yet. The project time is intense!

Model diagrams





THANKS

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