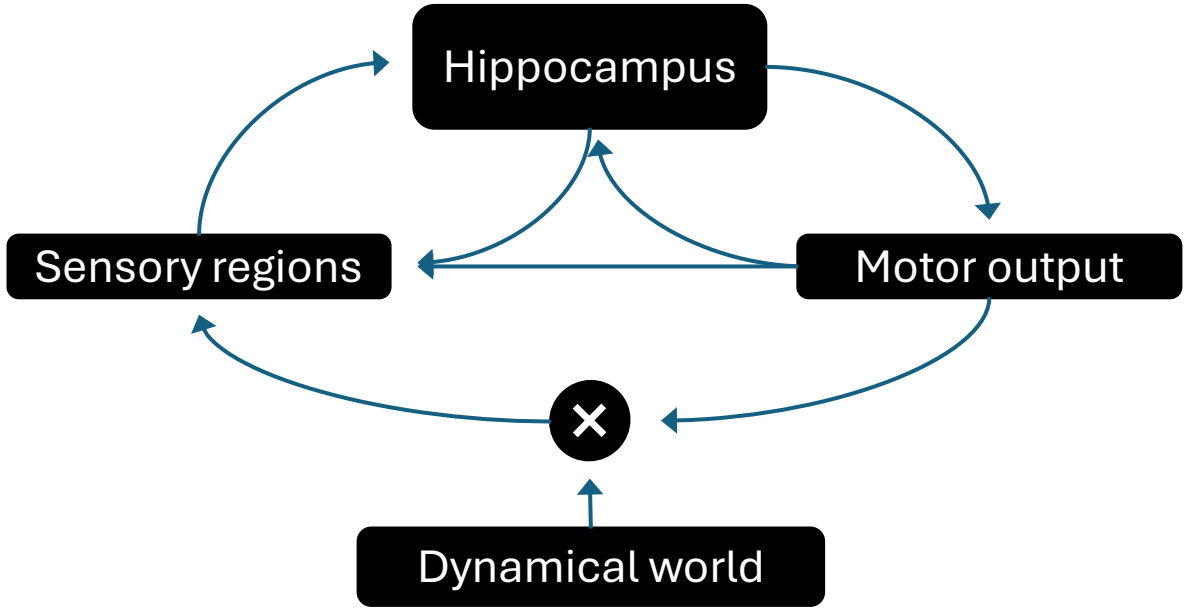
Sensory modulated interactions between olfactory bulb hippocampus and behavior



Cognitive maps & navigation

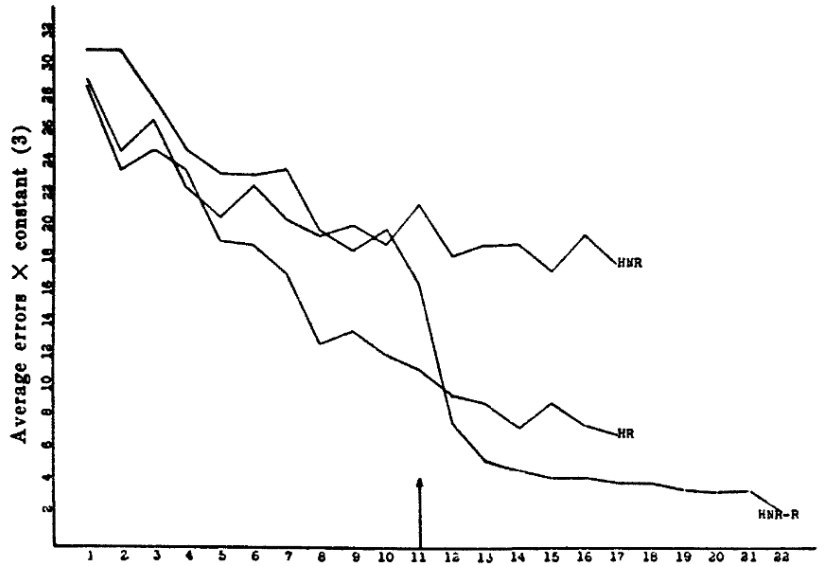
- Rats form internal cognitive ‘field maps’ of environment
  - Latent learning

VOL. 55, No. 4 JULY, 1948

THE PSYCHOLOGICAL REVIEW

COGNITIVE MAPS IN RATS AND MEN [1]

BY EDWARD C. TOLMAN
University of California



Error curves for HR, HNR, and HNR-R

(Tolman, 1948)

Hippocampus & cognitive maps

- Hippocampus necessary for human episodic memory

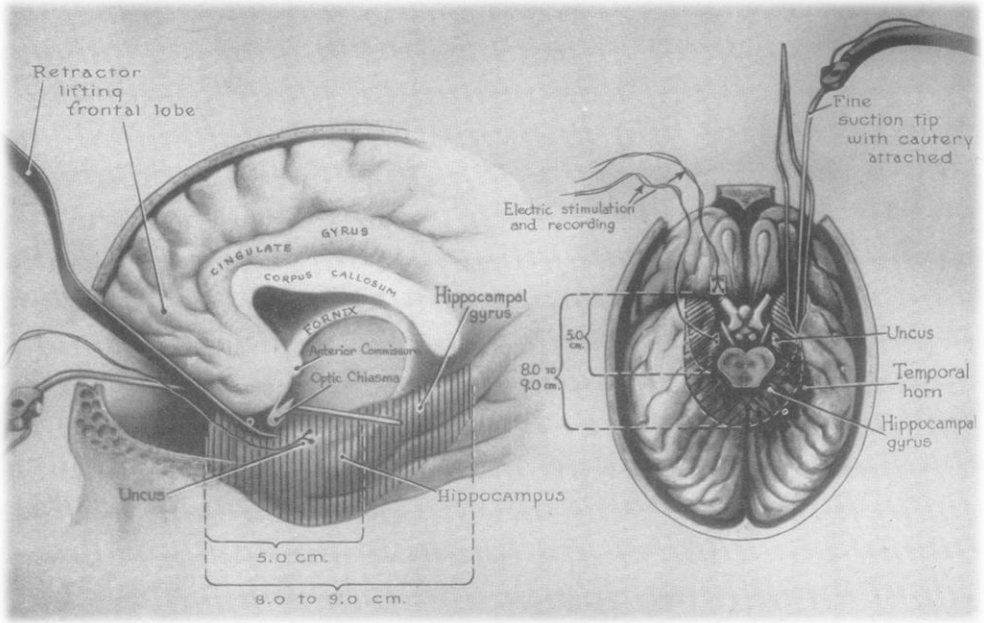
J. Neurol. Neurosurg. Psychiat., 1957, 20, 11.

LOSS OF RECENT MEMORY AFTER BILATERAL HIPPOCAMPAL LESIONS

BY

WILLIAM BEECHER SCOVILLE and BRENDA MILNER

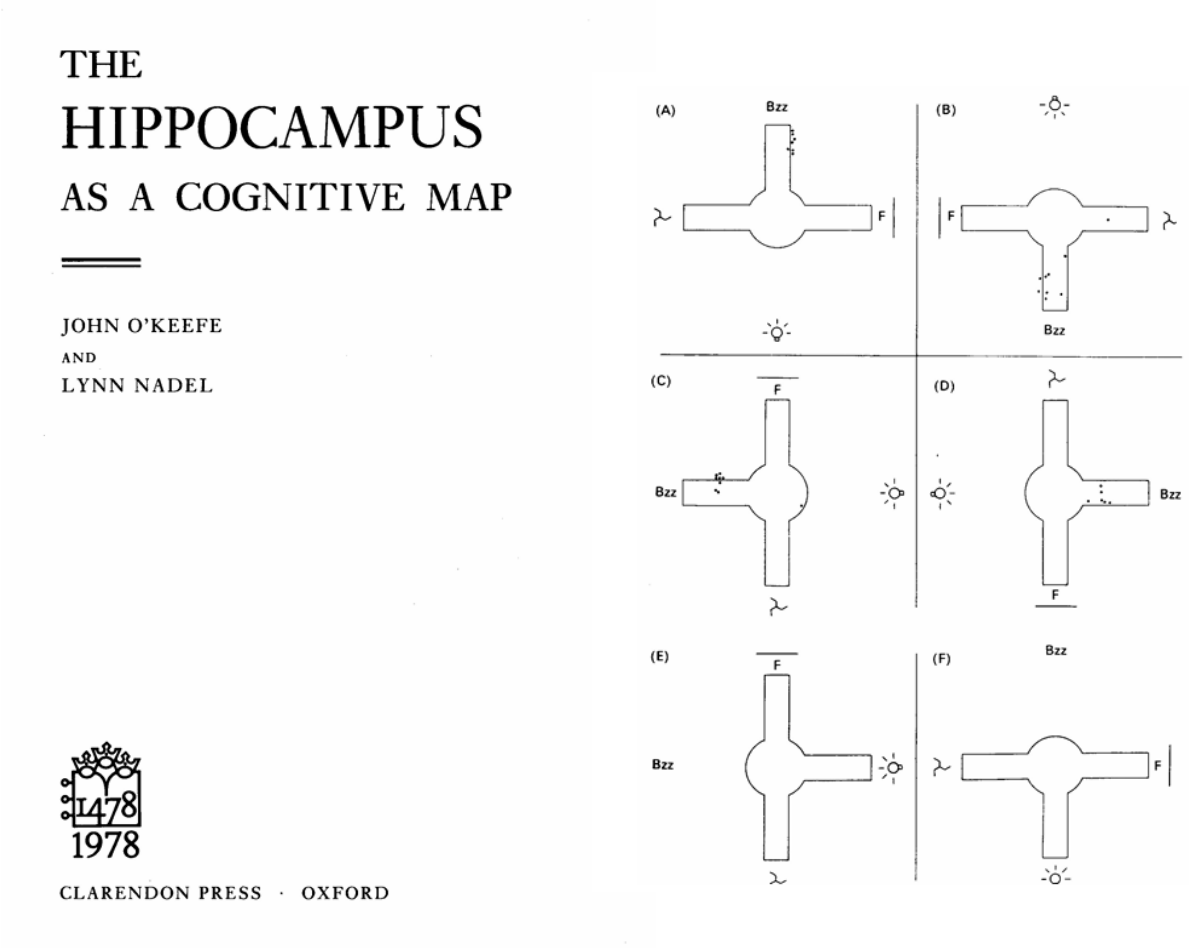
From the Department of Neurosurgery, Hartford Hospital, and the Department of Neurology and Neurosurgery, McGill University, and the Montreal Neurological Institute, Canada



(Scoville and Milner, 1957)

Hippocampus & cognitive maps

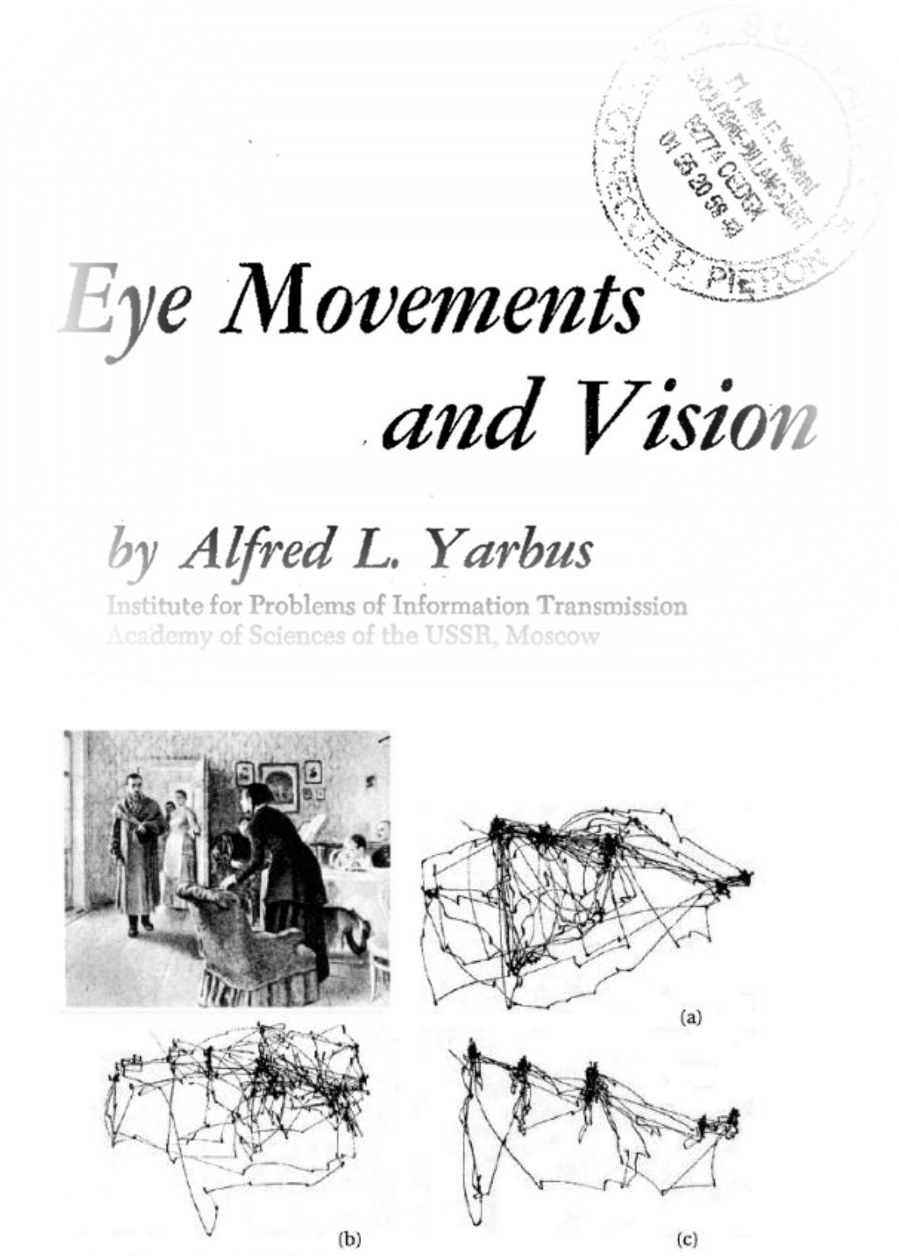
- Hippocampus necessary for human episodic memory
- Hippocampal neurons fire with selective spatial tunings



(O'Keefe & Nadel, 1978)

Active sampling

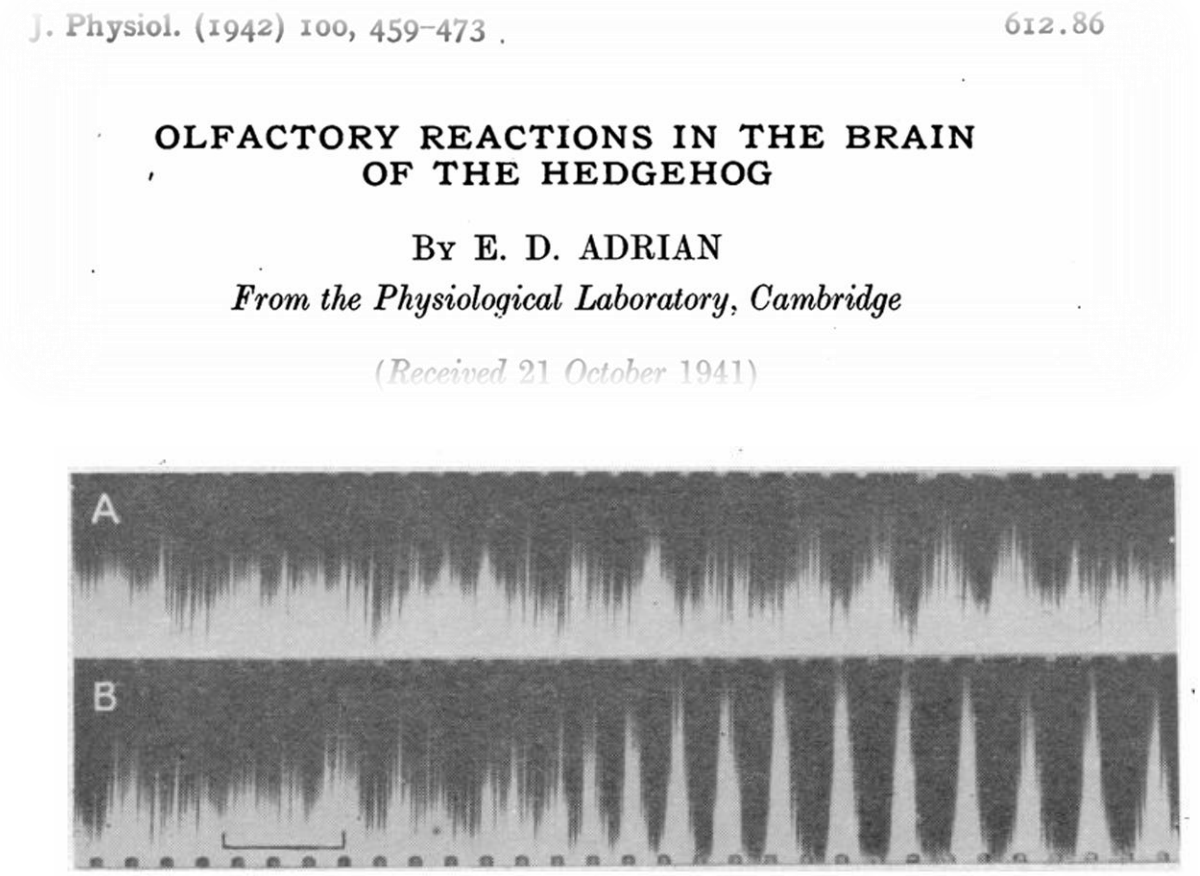
- Being-in-the-world is an active process



(Yarbus, 1967)

Active sampling

- Being-in-the-world is an active process
- Neuronal oscillations in sensory regions track sampling behavior



J. Physiol. (1942) 100, 459–473. 612.86

OLFACTORY REACTIONS IN THE BRAIN OF THE HEDGEHOG

By E. D. ADRIAN

From the Physiological Laboratory, Cambridge

(Received 21 October 1941)

(Adrian, 1942)

Active sampling

- Being-in-the-world is an active process
- Neuronal oscillations in sensory regions track sampling behavior
- Hippocampal oscillations selectively coherent with sensory region and behavior

0270-6474/82/0212-1705$02.00/0

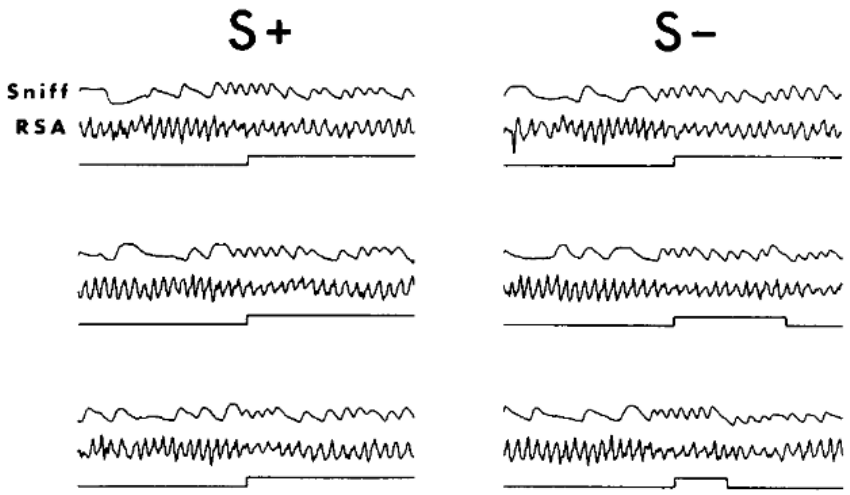
The Journal of Neuroscience
Vol. 2, No. 12, pp. 1705–1717
December 1982

TEMPORAL RELATIONSHIP BETWEEN SNIFFING AND THE LIMBIC θ RHYTHM DURING ODOR DISCRIMINATION REVERSAL LEARNING[1]

FOTEOS MACRIDES,[2] HOWARD B. EICHENBAUM,* AND WILLIAM B. FORBES

*Worcester Foundation for Experimental Biology, Shrewsbury, Massachusetts 01545 and *Department of Biology, Wellesley College, Wellesley, Massachusetts 02181*

Received May 24, 1982; Revised July 26, 1982; Accepted August 24, 1982



(Macrides et al., 1982)

Self-organized mapping through action

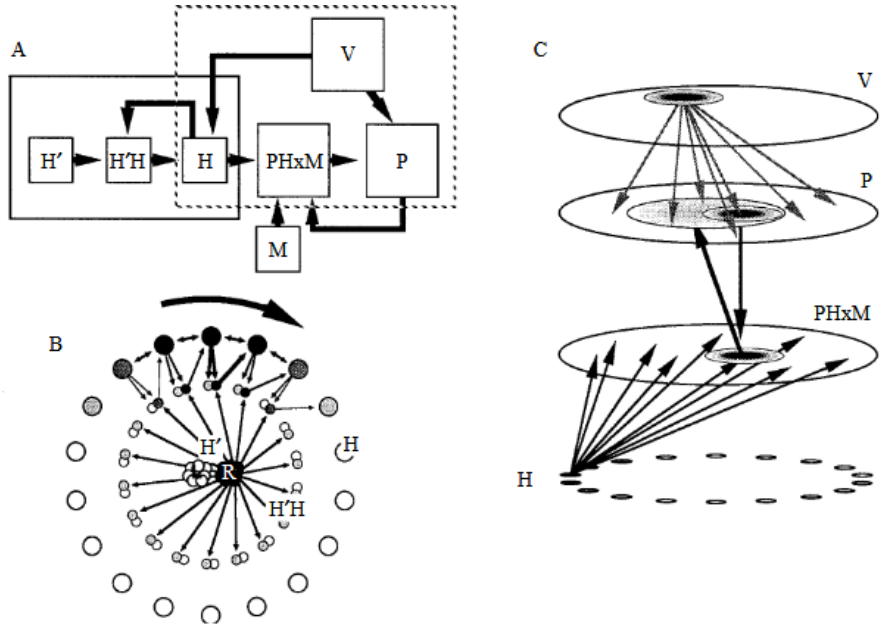
- Grid and place cells rely on body-derived signals
  - Path integration

The Journal of Experimental Biology 199, 173–185 (1996)
Printed in Great Britain © The Company of Biologists Limited 1996
JEB0129

DECIPHERING THE HIPPOCAMPAL POLYGLOT: THE HIPPOCAMPUS AS A PATH INTEGRATION SYSTEM

B. L. McNAUGHTON, C. A. BARNES, J. L. GERRARD, K. GOTHARD, M. W. JUNG, J. J. KNIERIM, H. KUDRIMOTI, Y. QIN, W. E. SKAGGS, M. SUSTER AND K. L. WEAVER

Arizona Research Laboratories, Division of Neural Systems, Memory, and Aging, University of Arizona, Tucson, AZ 85724, USA



(McNaughton et al., 1996)

Self-organized mapping through action

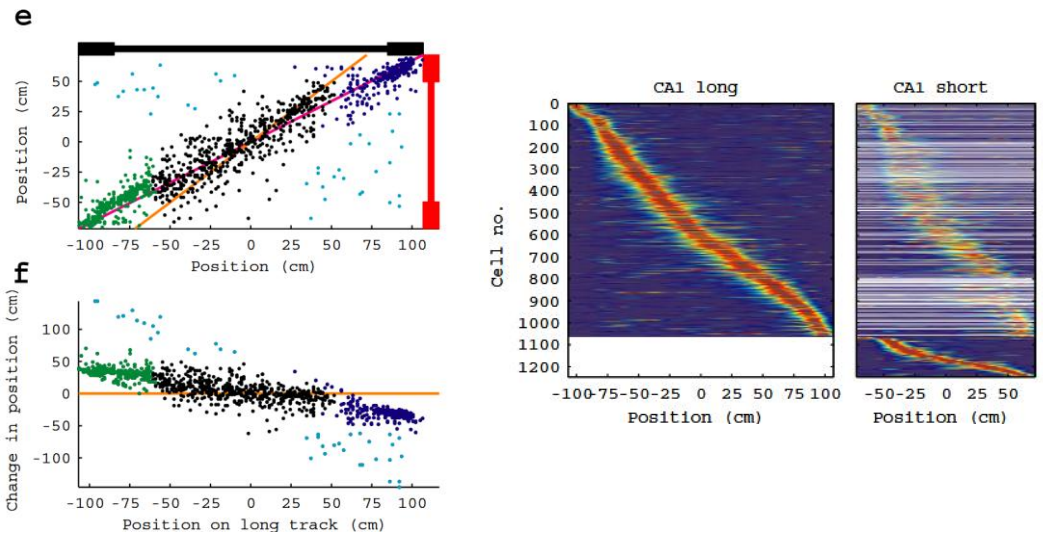
- Grid and place cells rely on body-derived signals
  - Path integration
- Context dependent place cells

13448 • The Journal of Neuroscience, December 10, 2008 • 28(50):13448–13456

Behavioral/Systems/Cognitive

Hippocampal Network Dynamics Constrain the Time Lag between Pyramidal Cells across Modified Environments

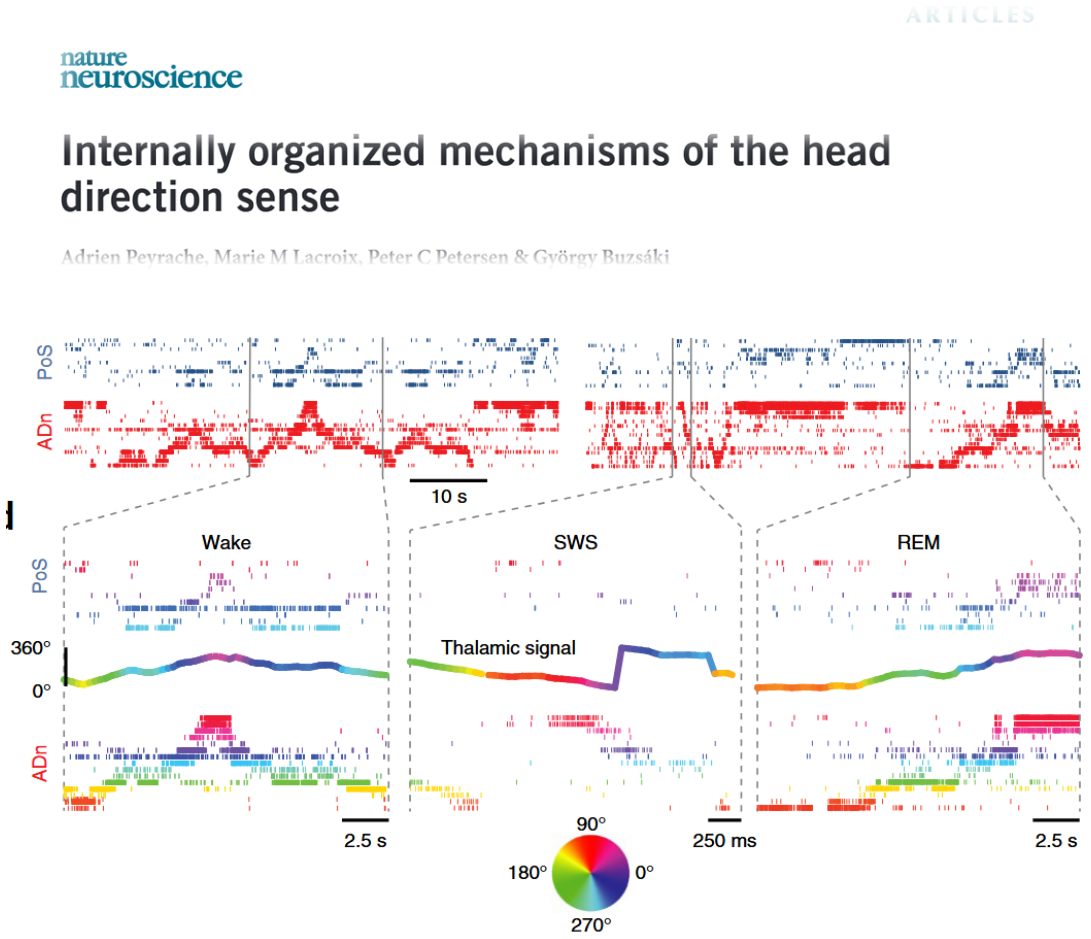
Kamran Diba and György Buzsáki
Center for Molecular and Behavioral Neuroscience, Rutgers University–Newark, Newark, New Jersey 07102



(Diba & Buzsáki, 2008)

Self-organized mapping through action

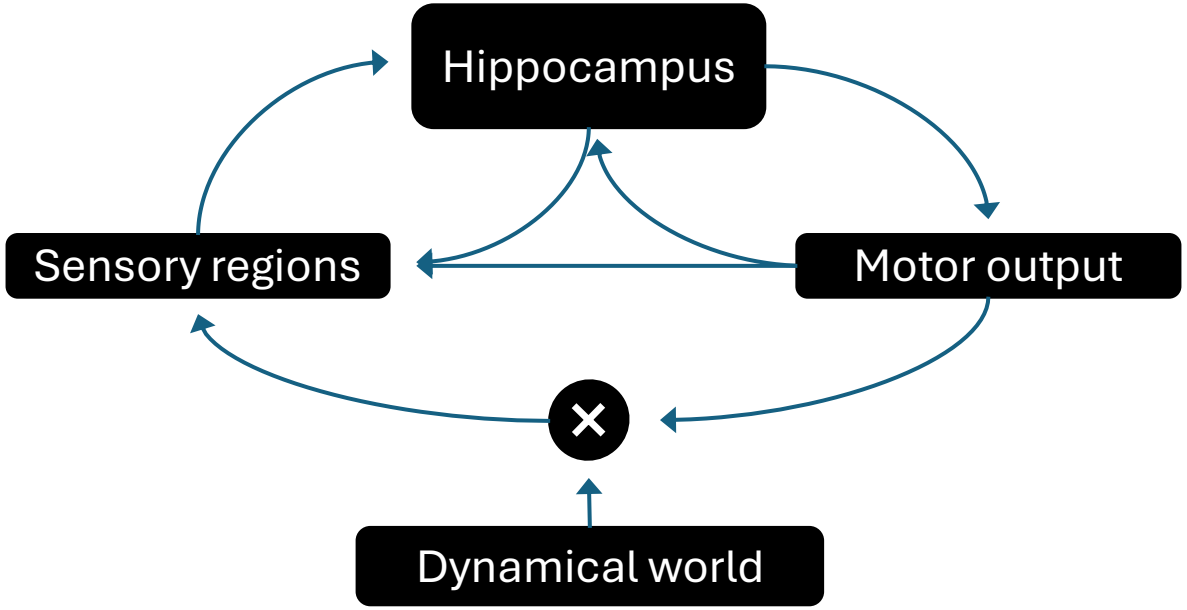
- Grid and place cells rely on body-derived signals
  - Path integration
- Context dependent place cells
- Single unit correlations maintained during sleep



(Peyrache et al., 2015)

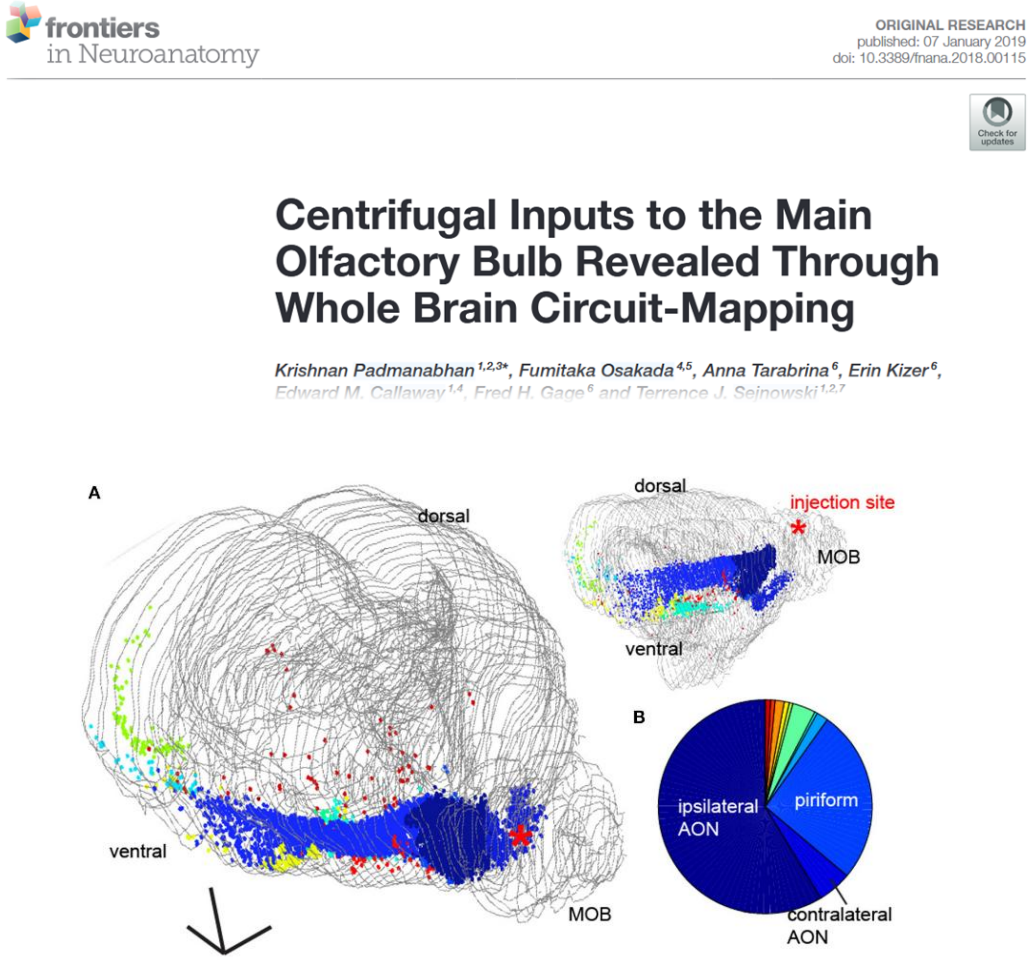
Sensory grounding through action

- Did I move or did the world change?
- Sensory inputs and action signals should converge in the brain
  - Where?
- Existing cognitive map used to compute change



Centrifugal inputs to the olfactory bulb

- Anterior olfactory nucleus
- Piriform cortex
- Horizontal limb of the diagonal band
- Amygdala
- Hippocampus
- Lateral entorhinal cortex
- Locus coeruleus



(Padmanabhan., 2019)

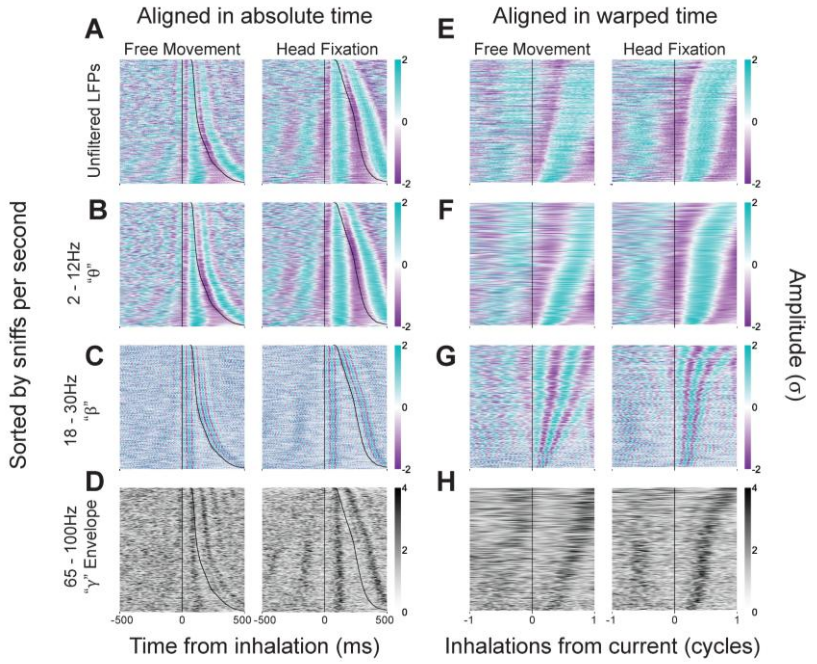
Sniffing and place

- OB LFPs track sniffing

Challenges in inferring breathing rhythms from olfactory bulb local field potentials

Sidney Rafilson, Nathan Hess, Teresa M. Findley, Matthew C. Smear

doi: https://doi.org/10.1101/2024.11.08.622727



(Rafilson et al., 2025)

Sniffing and place

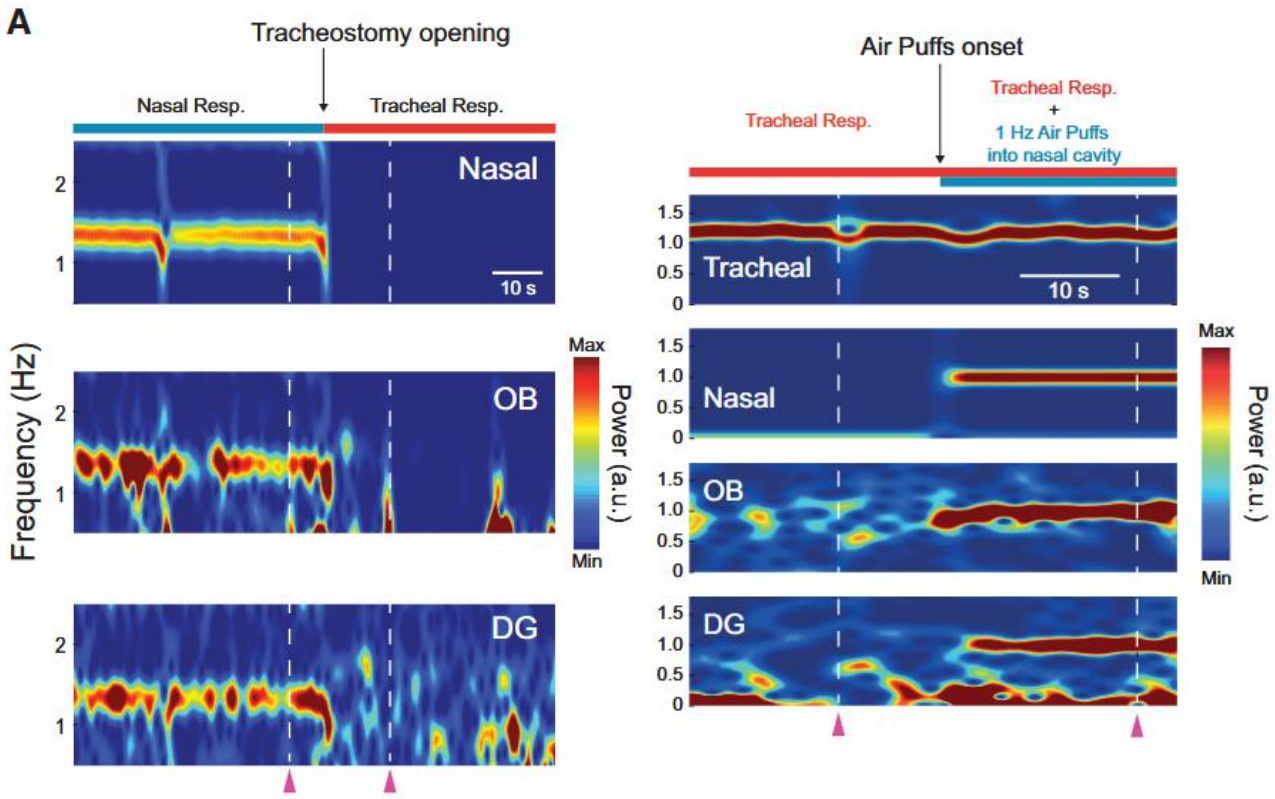
- OB LFPs track sniffing
  - Nasal respiration is necessary and sufficient

5338 • The Journal of Neuroscience, May 11, 2016 • 36(19):5338–5352

Systems/Circuits

A Respiration-Coupled Rhythm in the Rat Hippocampus Independent of Theta and Slow Oscillations

André L. V. Lockmann, Diego A. Laplagne, Richardson N. Leão, and Adriano B. L. Tort
Brain Institute, Federal University of Rio Grande do Norte, RN 59056-450, Brazil



(Lockmann et al., 2016)

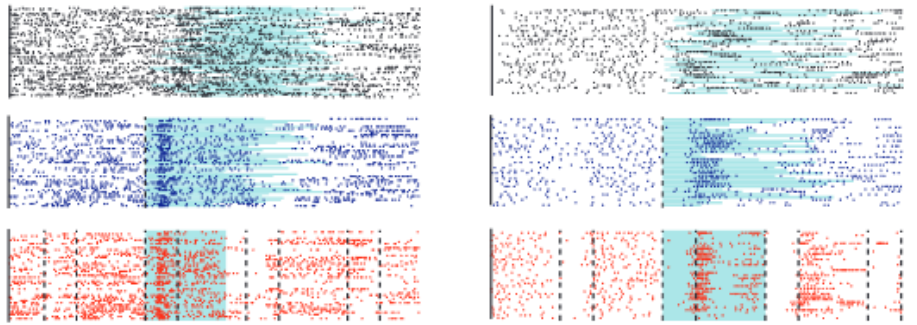
Sniffing and place

- OB LFPs track sniffing
  - Nasal respiration is necessary and sufficient
- Single units tuned to time/phase in sniff cycle

nature neuroscience

Precise olfactory responses tile the sniff cycle

Roman Shusterman[1], Matthew C Smear[1,2], Alexei A Koulakov[3] & Dmitry Rinberg[1]



(Shusterman et al., 2011)

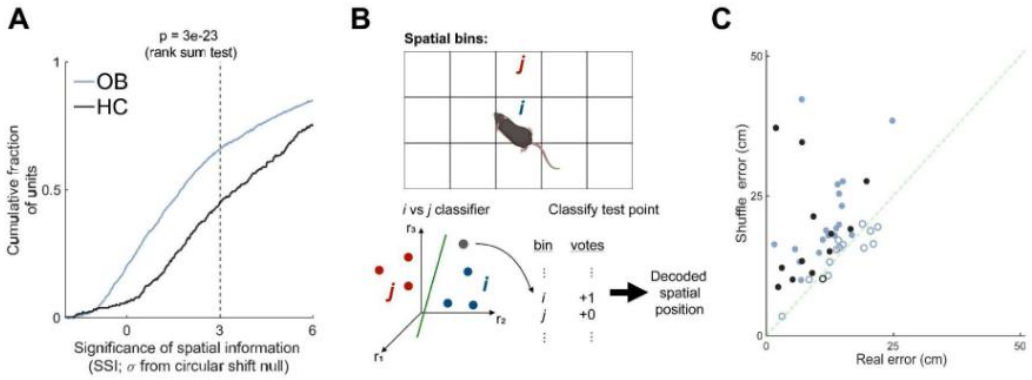
Sniffing and place

- OB LFPs track sniffing
  - Nasal respiration is necessary and sufficient
- Single units tuned to time/phase in sniff cycle
- Single units tuned to place and population encodes allocentric space

Neuroscience

Olfactory bulb tracks breathing rhythms and place in freely behaving mice

Scott C Sterrett, Teresa M Findley, Sidney E Rafilson, Morgan A Brown, Aldis P Weible, Rebecca Marsden, Takisha Tarvin, Michael Wehr, James M Murray, Adrienne L Fairhall, Matthew C Smear



(Sterrett et al., 2025)

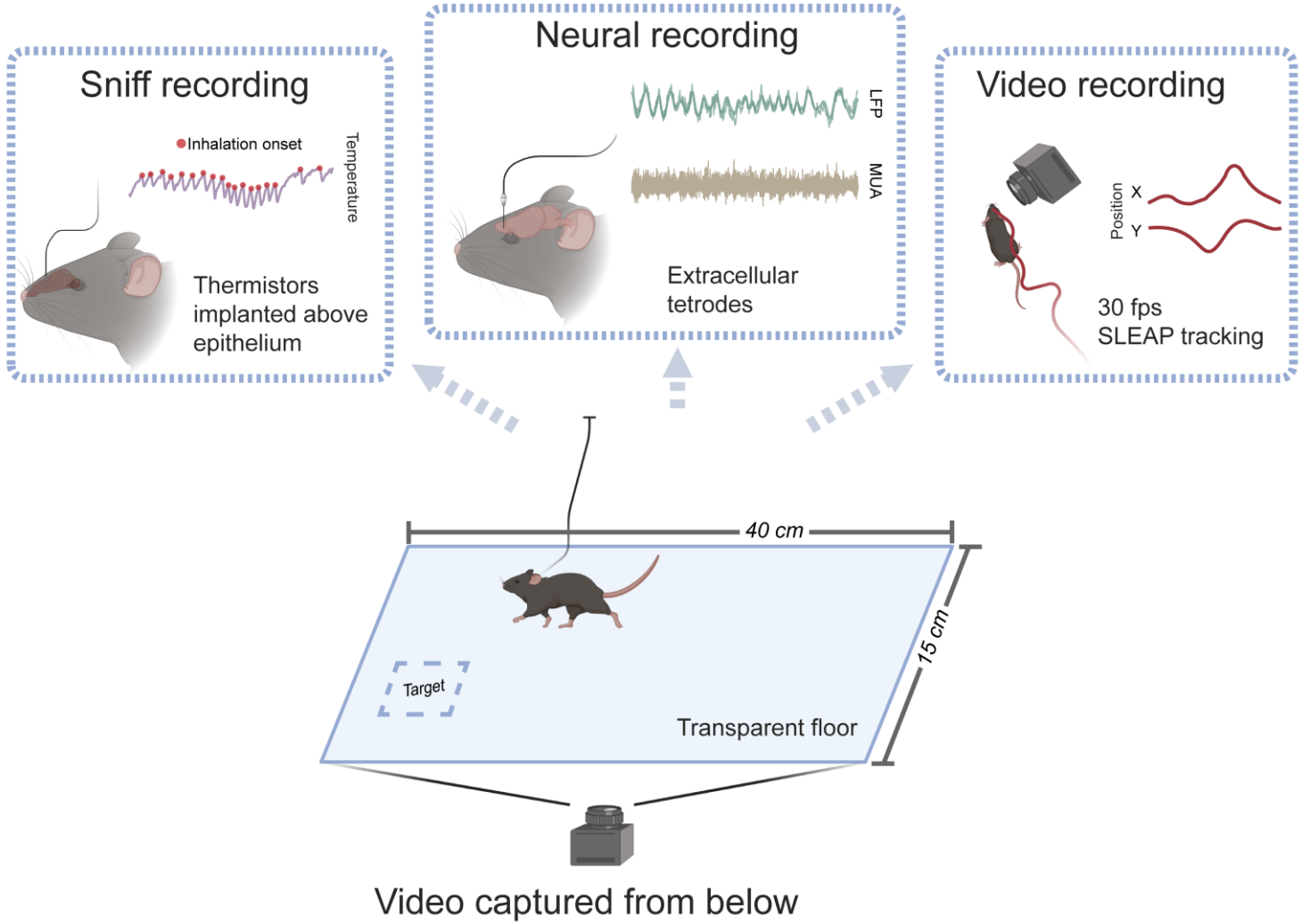
Research Question

Are sniffing and spatial information formed from feedforward sensory inputs or sent through centrifugal feedback?

- If information depends on feed-forward sensory inputs it cannot be used as an action grounding signal
  - Nor does it represent a cognitive map
- Any information that remains in the absence of sensory inputs could be used for action grounding or represent the neuronal substrate of the cognitive map

Experimental design

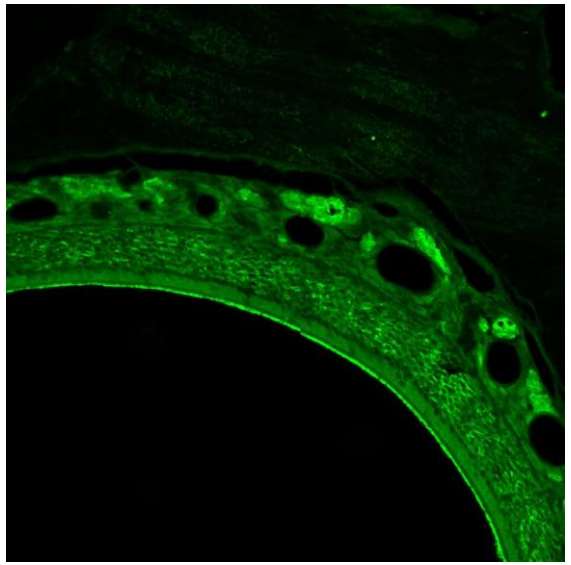
- Foraging like task (clickbait)
- Thermistor to record sniffing
- Tetrodes implanted in OB and CA1
- Bottom-up video tracking



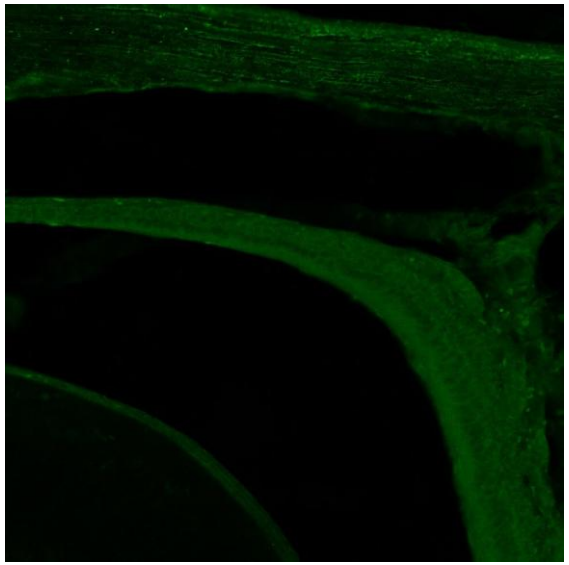
Experimental design

- Foraging like task (clickbait)
- Thermistor to record sniffing
- Tetrodes implanted in OB and CA1
- Bottom-up video tracking
- MMZ to ablate olfactory sensory neurons

Pre injection

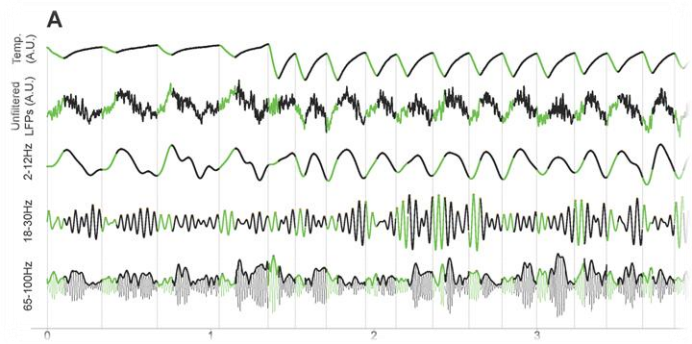


Post injection

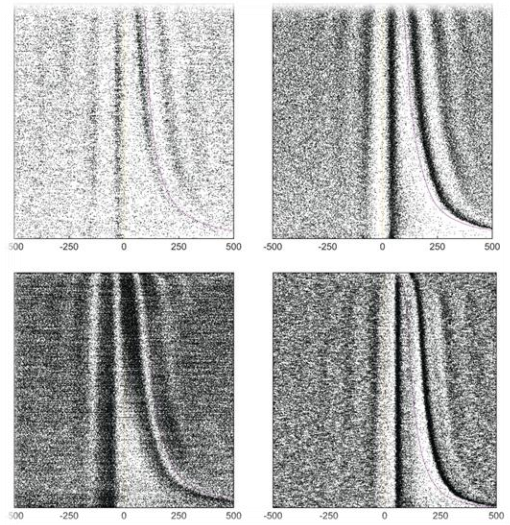


Results overview

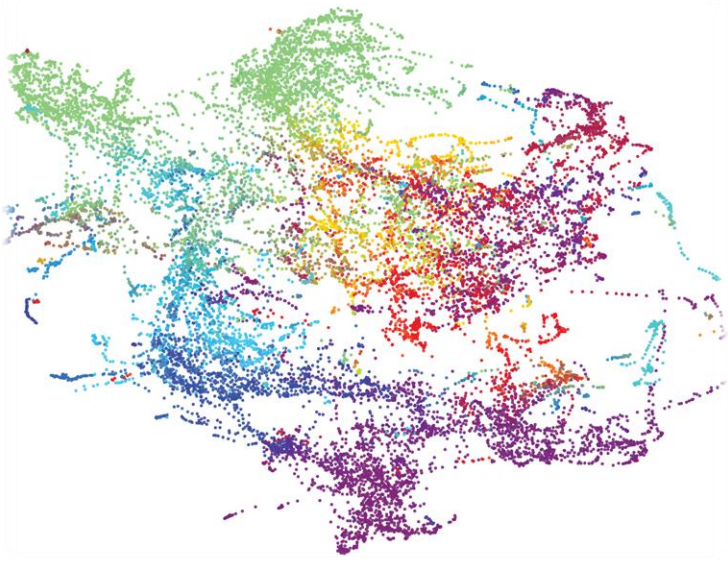
Local field potentials



Single unit spiking

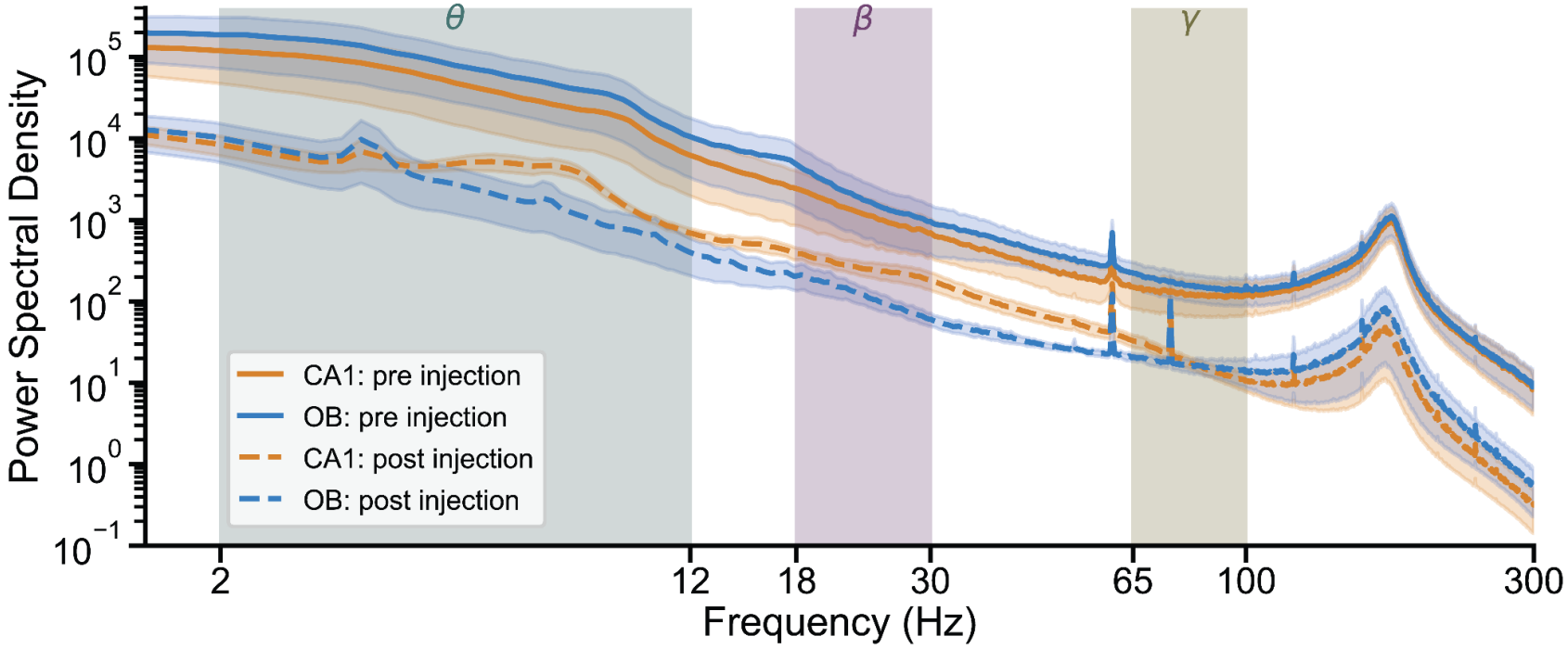


Population activity



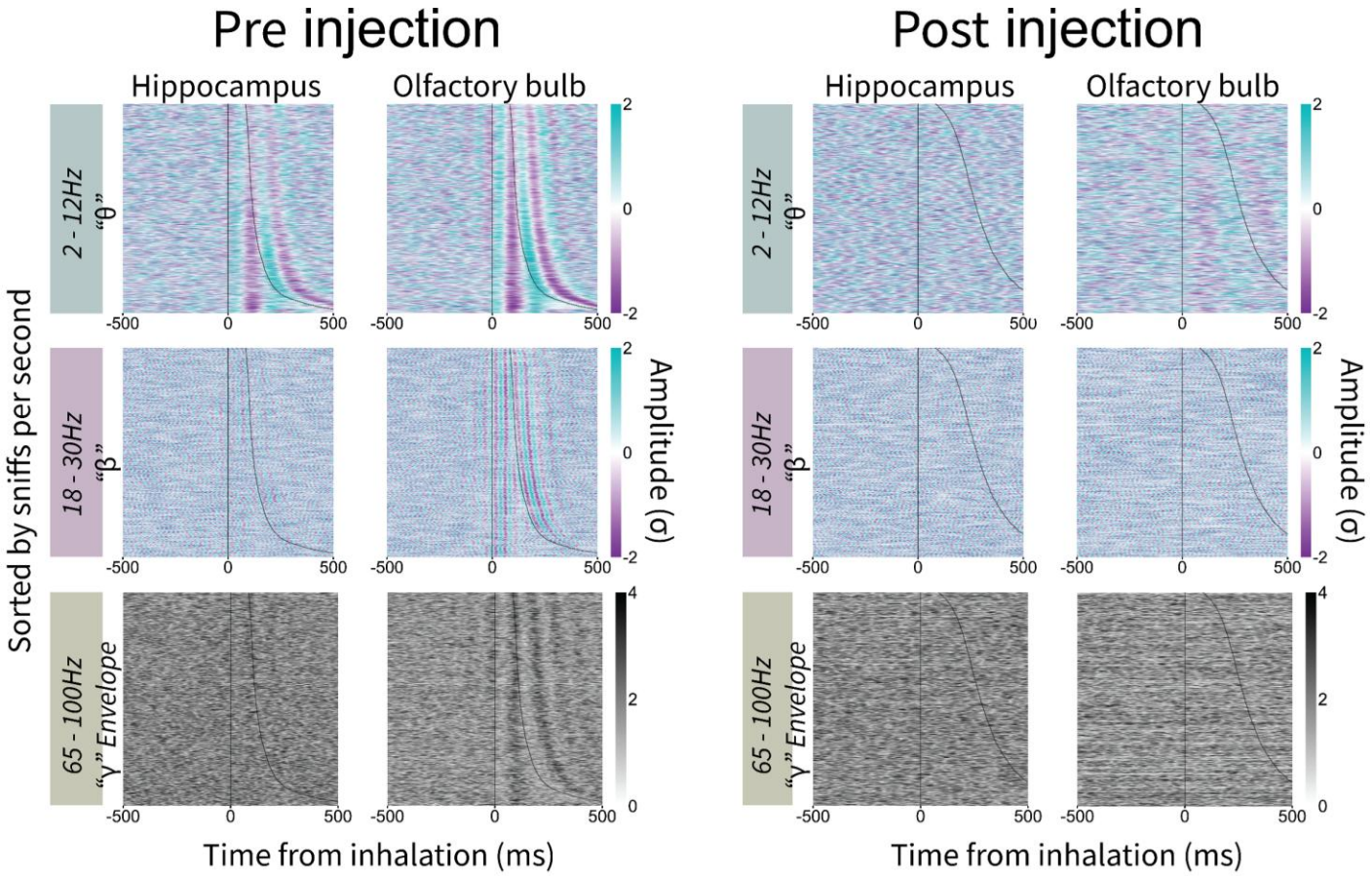
Sniff synchronous local field potentials

- MMZ uniformly reduced power across spectra



Sniff synchronous local field potentials

- MMZ uniformly reduced power across spectra
- LFPs track respiration



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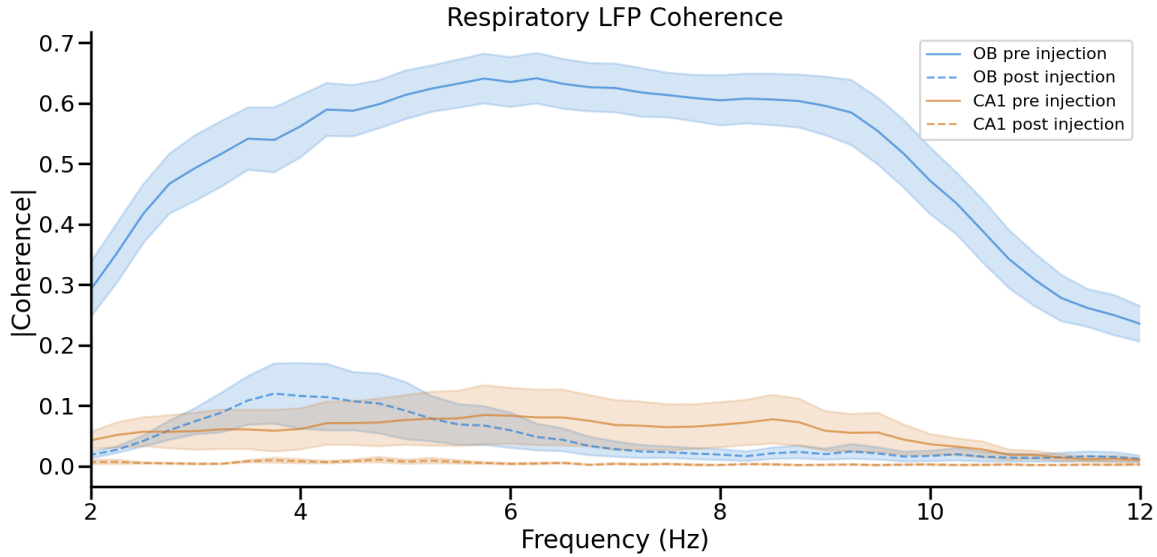

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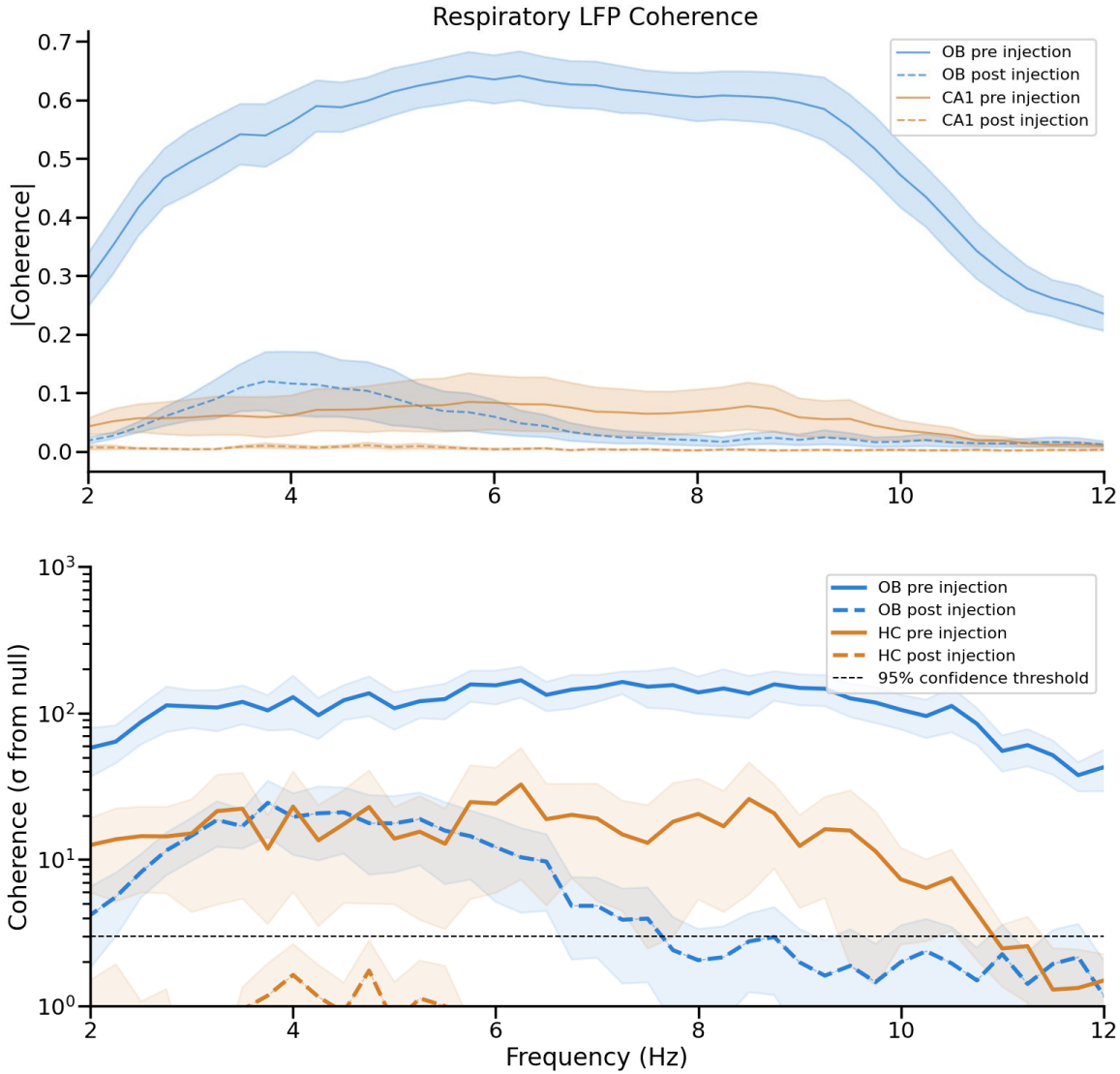

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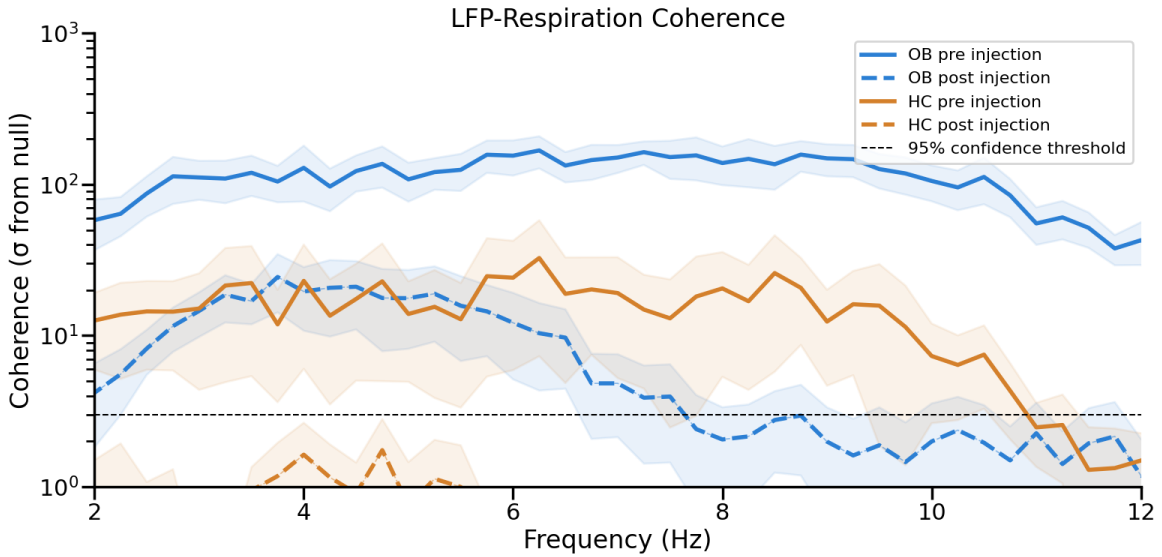
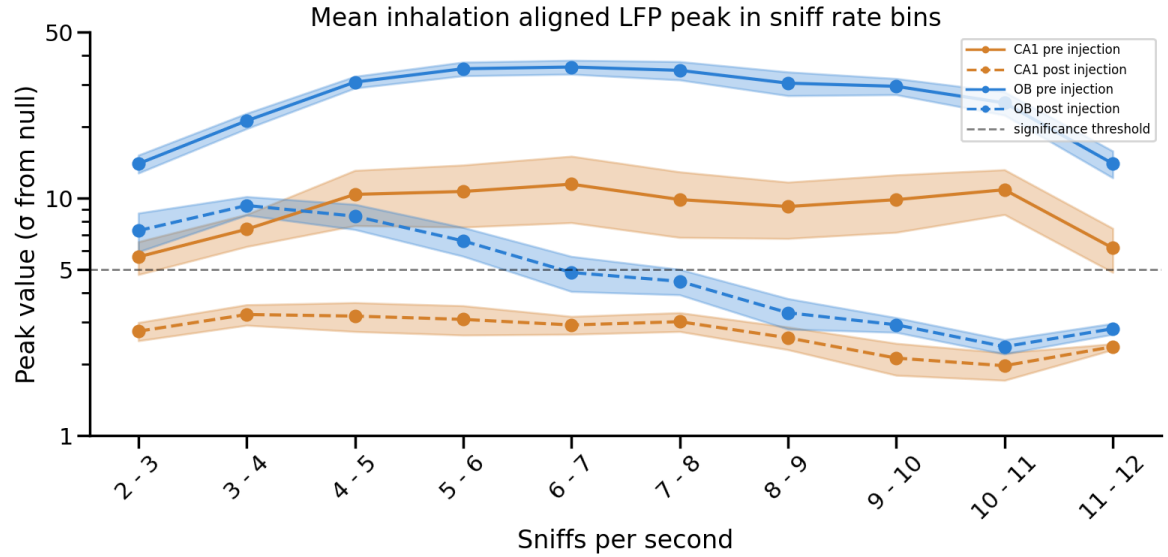
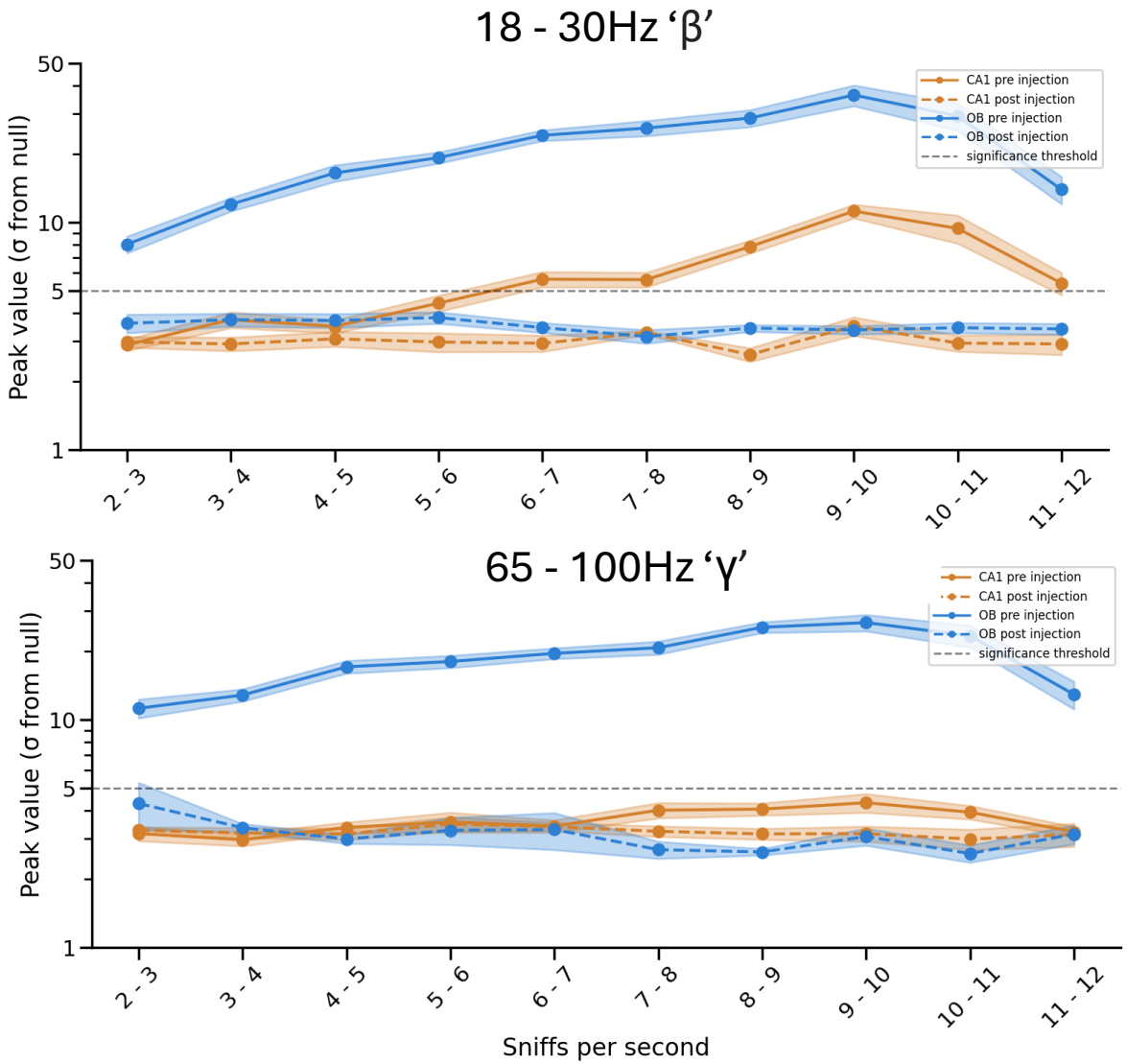




Sniff synchronous local field potentials

- MMZ uniformly reduced power across spectra
- LFPs track respiration
- MMZ disrupts alignment with respiration



Sniff synchronous local field potentials

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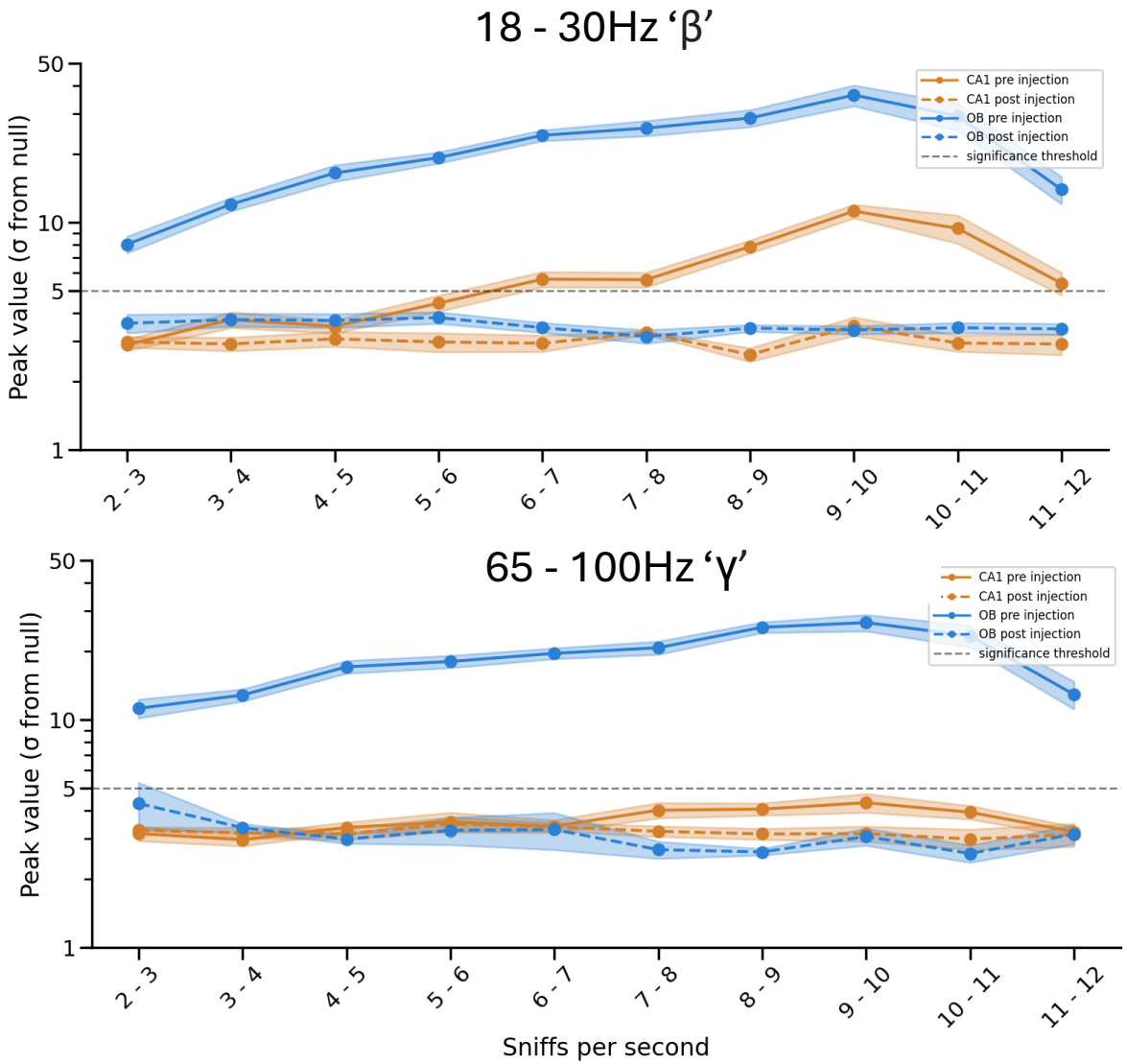
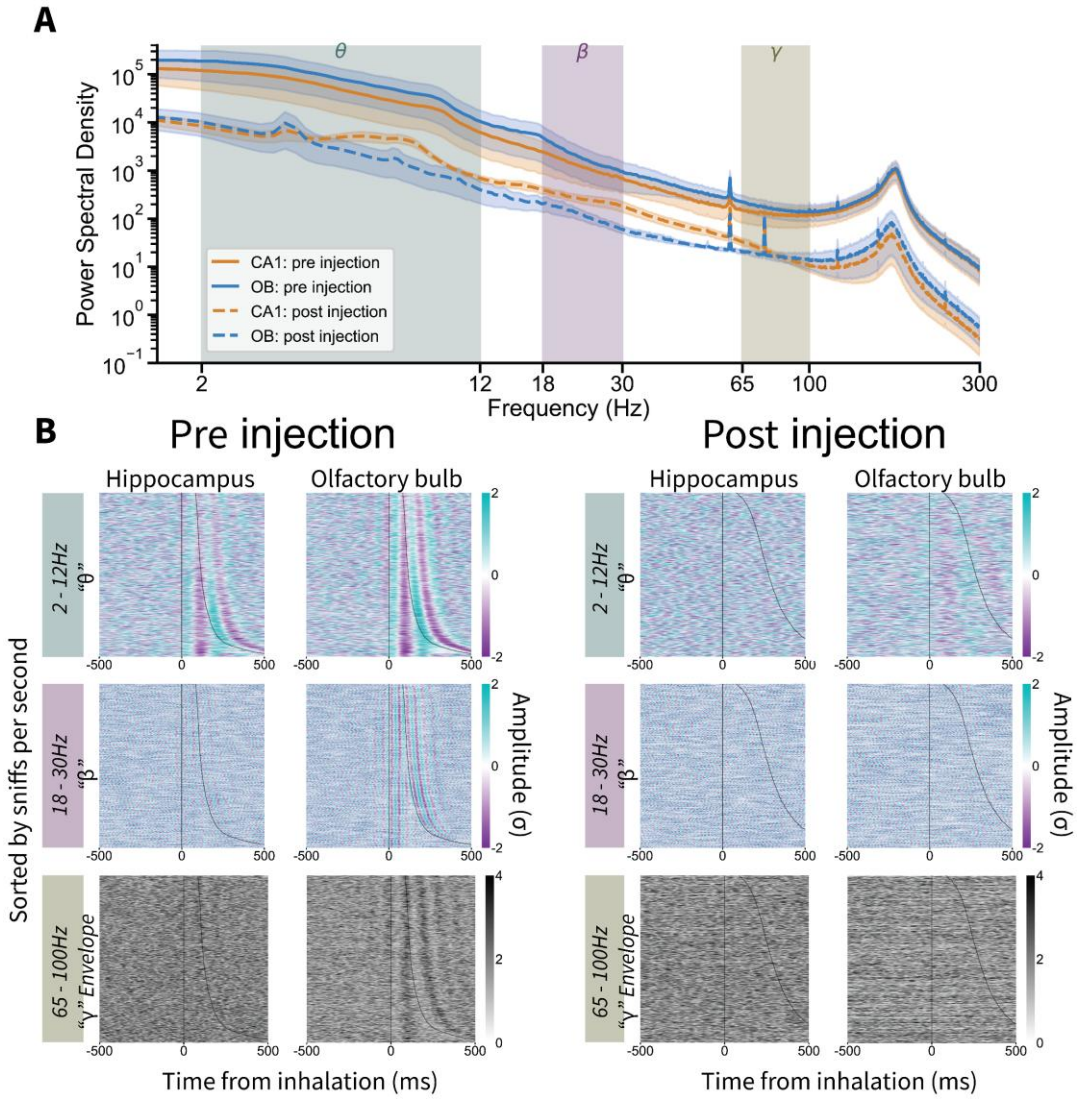
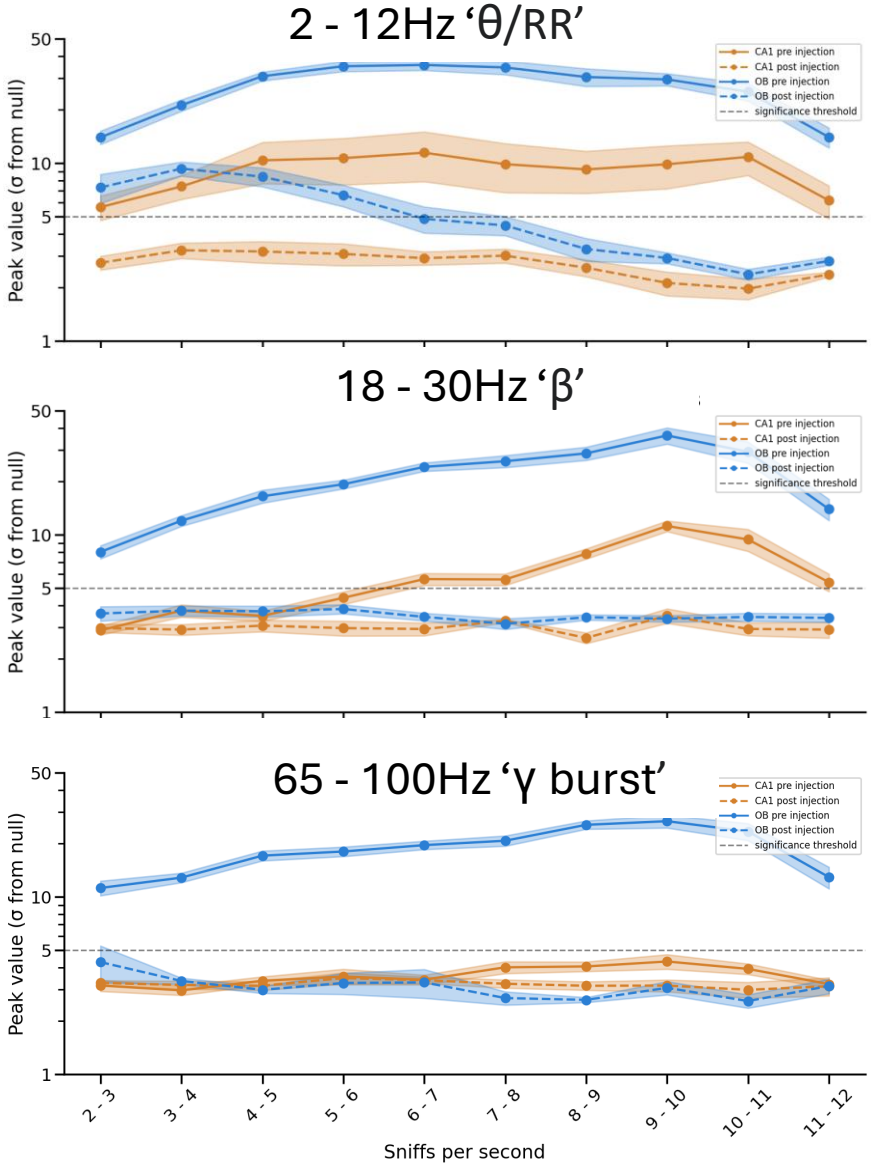
- LFPs track respiration
- MMZ disrupts alignment with respiration



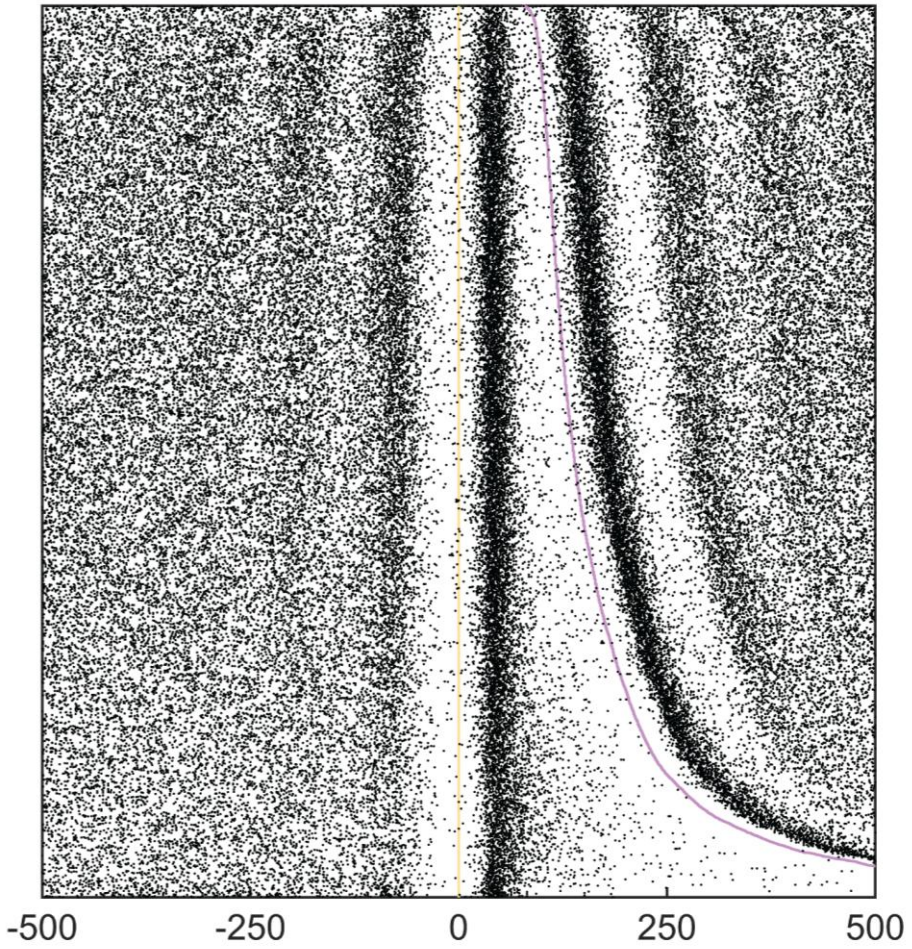
Sniff synchronous local field potentials





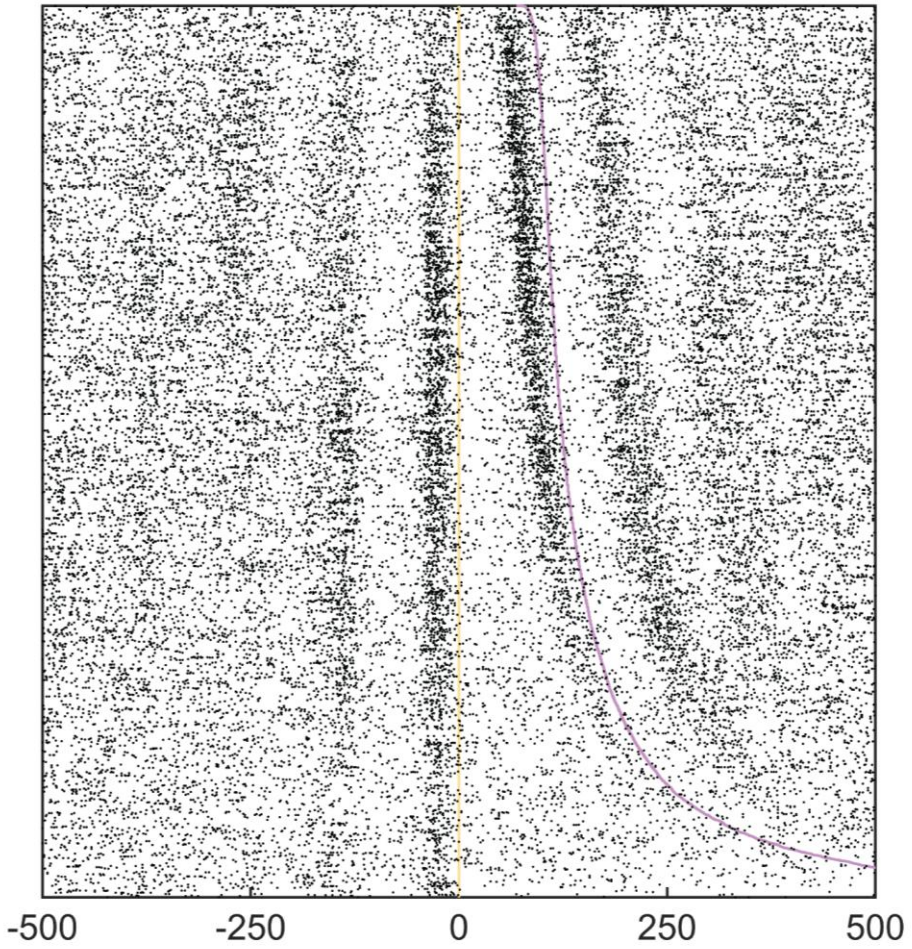
Sniff synchronous spiking

- OB single units follow inhalation



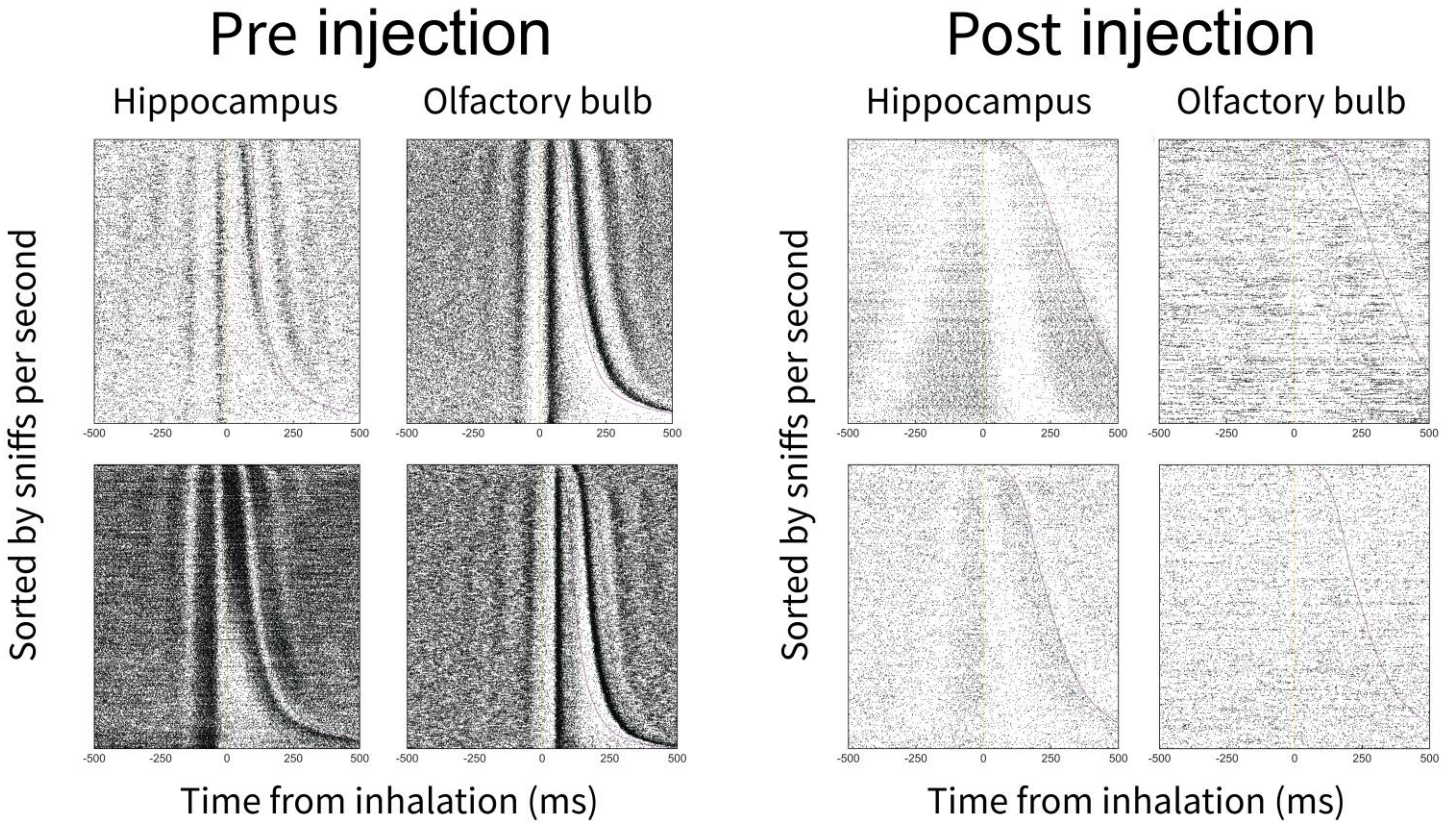
Sniff synchronous spiking

- OB single units follow inhalation
- CA1 single units precede inhalation



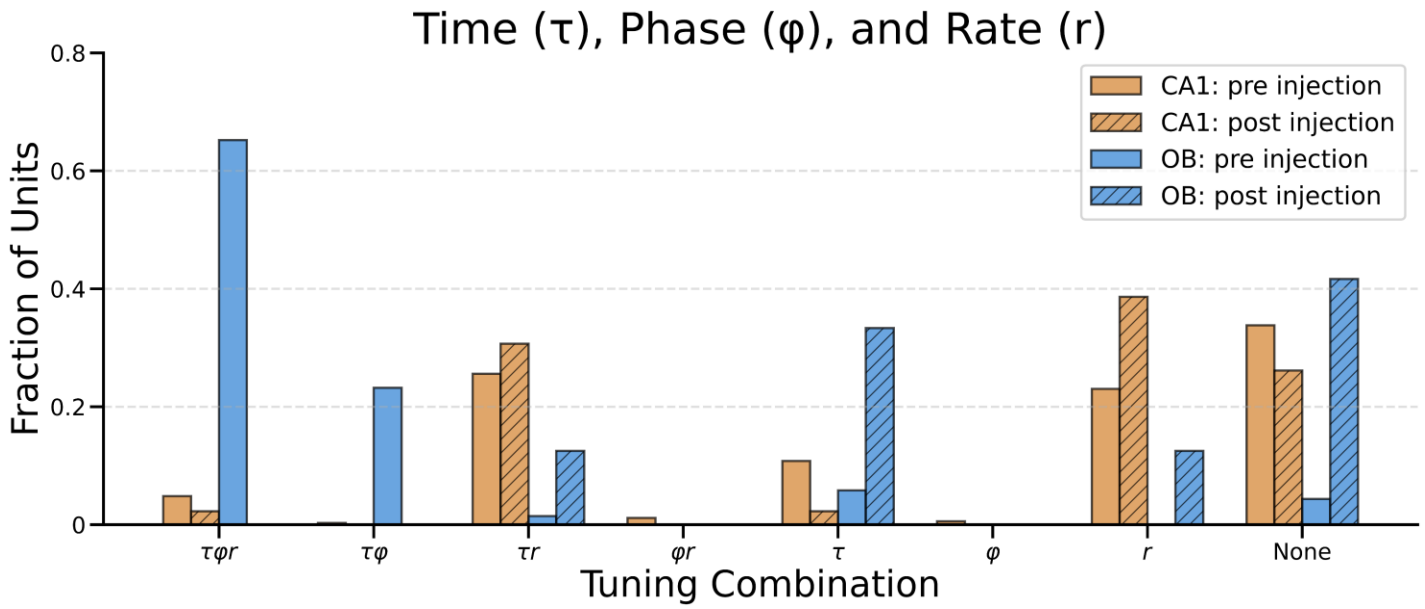
Sniff synchronous spiking

- OB single units follow inhalation
- CA1 single units precede inhalation
- MMZ disrupts tuning in OB but not CA1



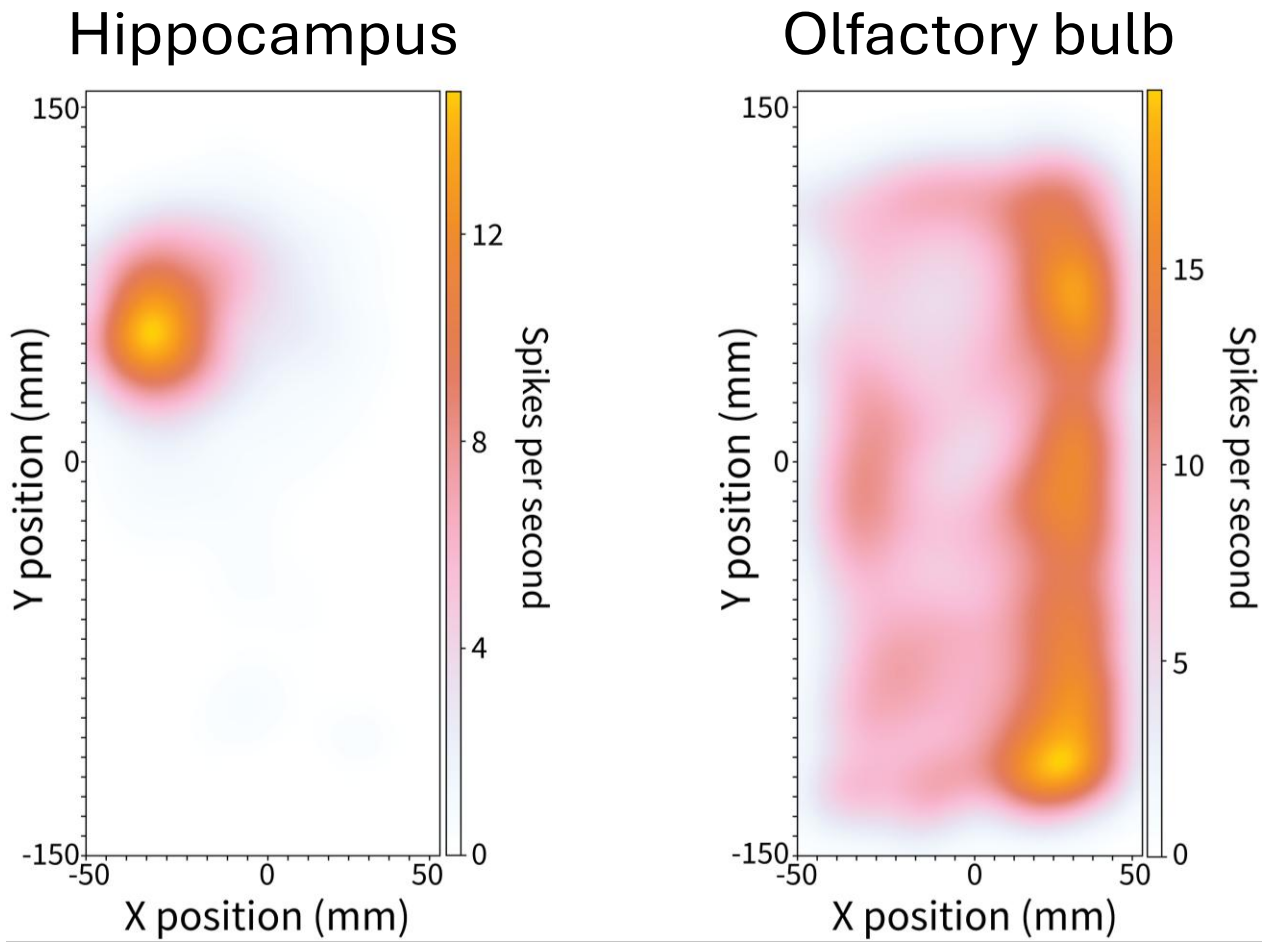
Sniff synchronous spiking

- OB single units follow inhalation
- CA1 single units precede inhalation
- MMZ disrupts tuning in OB but not CA1
- PGAM quantifies tuning



Spatial olfactory code

- Place cells in CA1 and spatial tuned OB units



Spatial olfactory code

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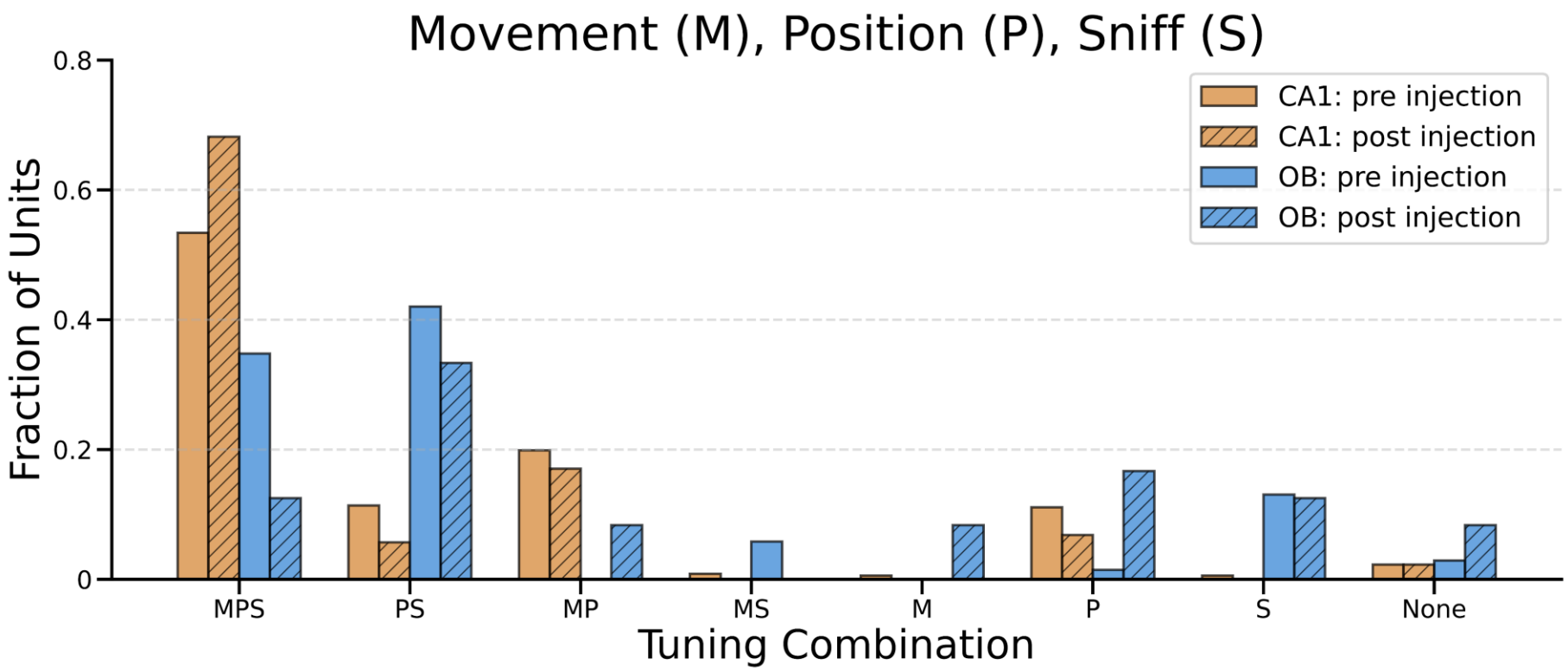
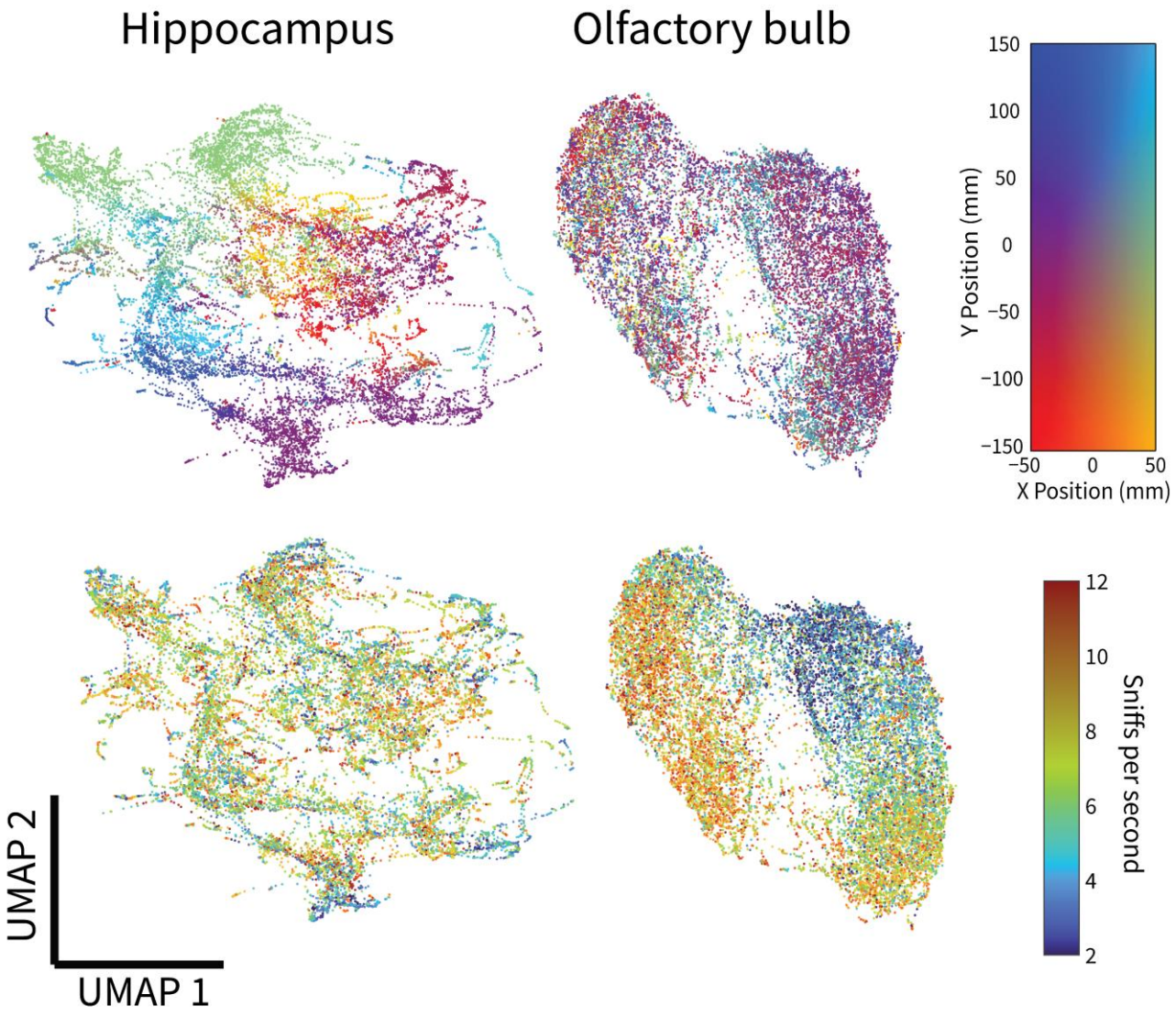
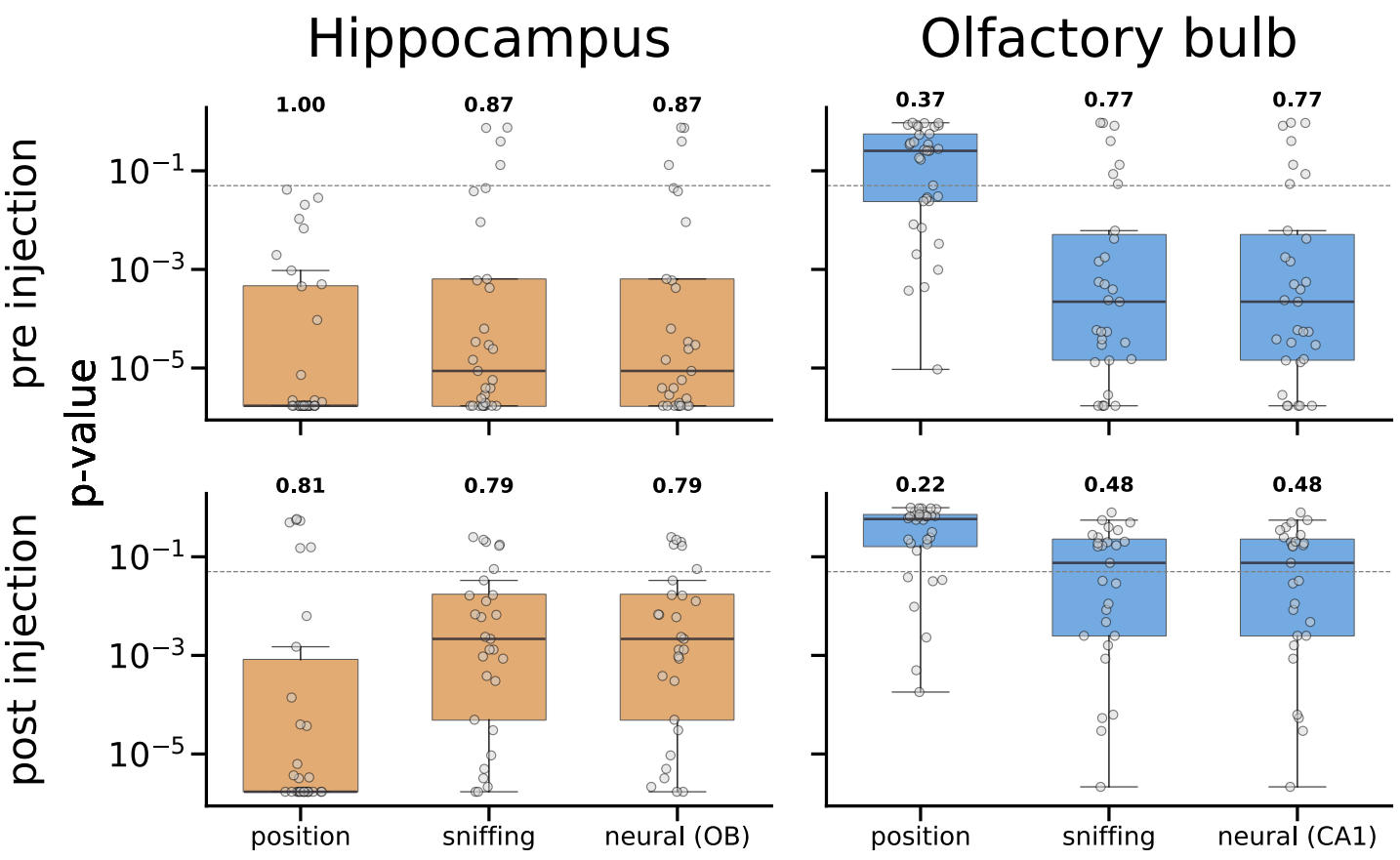


Population correlations



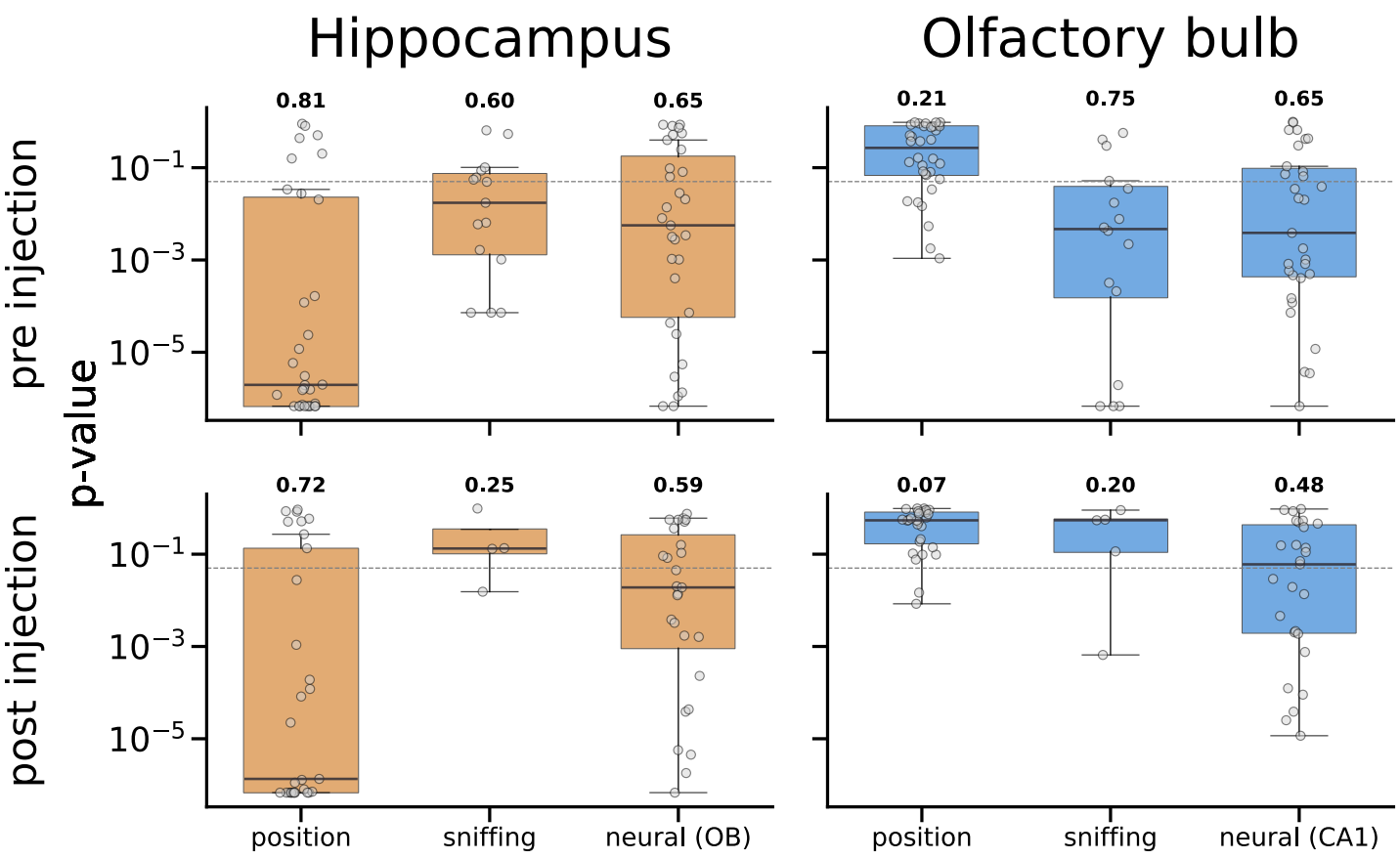
- Populations encodes position and sniff rates

Population correlations



- Populations encodes position and sniff rates
- LSTM decoding

Population correlations



- Populations encodes position and sniff rates
- LSTM decoding
- Kalman filter decoding

Discussion

- Olfactory bulb encodes allocentric space in the absence of chemosensory inputs
- Precise timing of OB activity relative to respiration depends on chemosensory inputs
  - Single unit spiking, beta and gamma oscillations
- Hippocampal LFPs lose synchrony with respiration after ablation of olfactory sensory neurons

Respiratory oscillations as a global timing mechanism