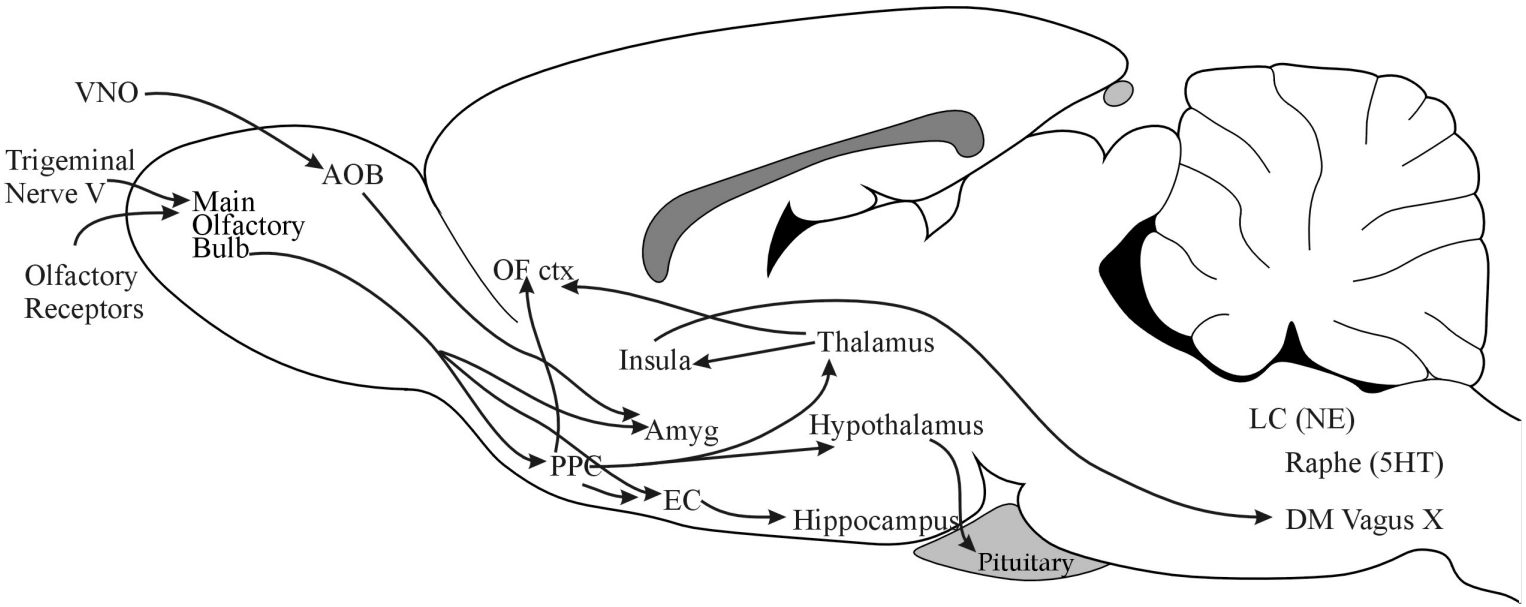
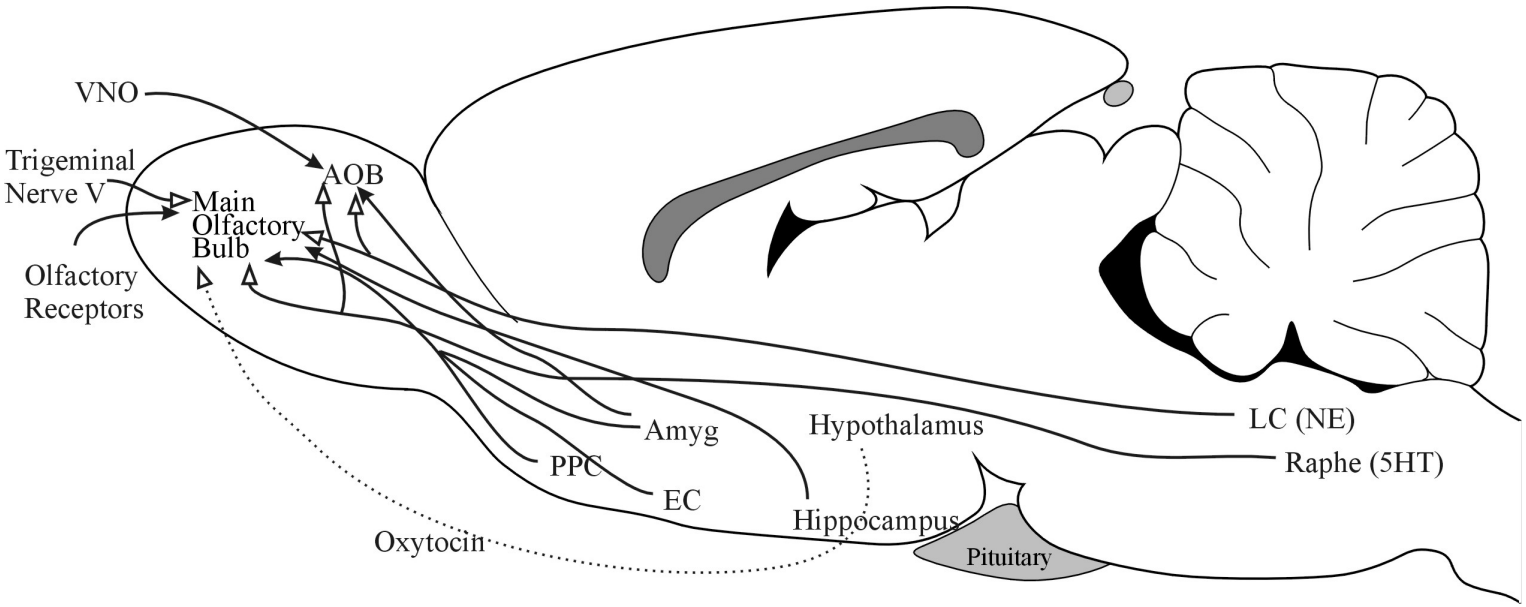
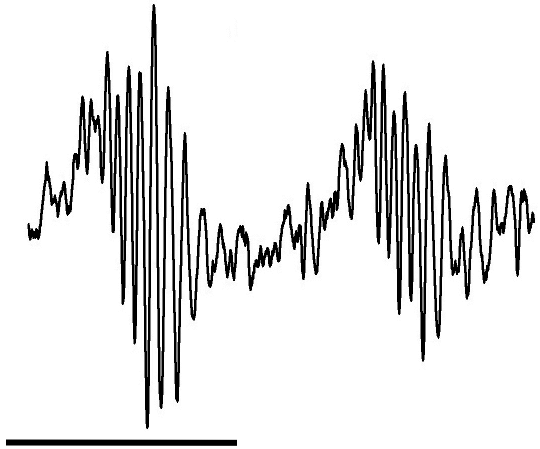
Mammalian Olfactory System: Feed-Forward

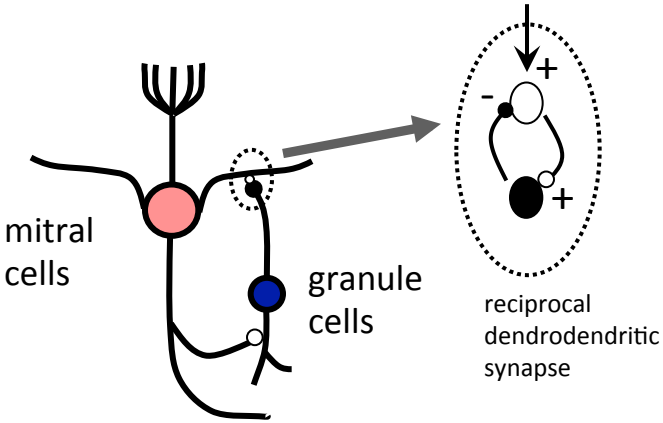


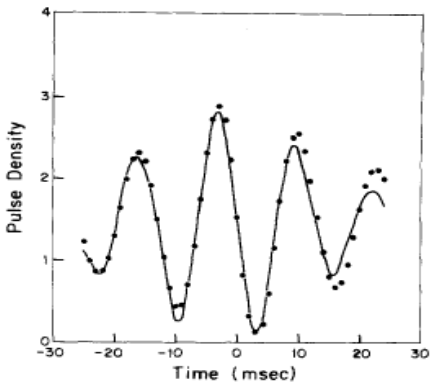
Mammalian Olfactory Bulb Input

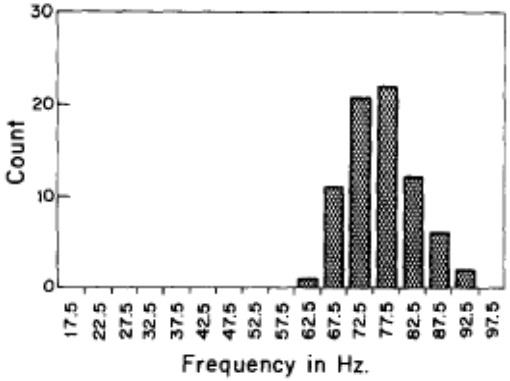


The LFP gamma oscillation predicts M/T cell firing patterns



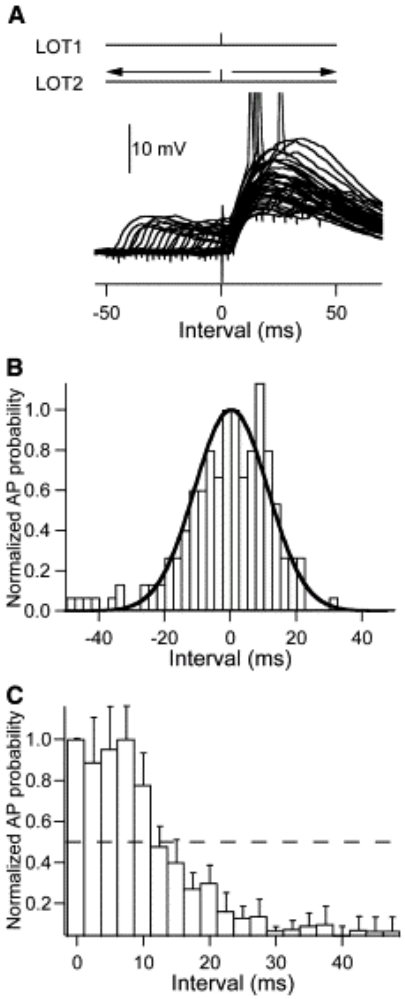






Eeckman & Freeman, *Brain Research* 1990

What good are oscillations?

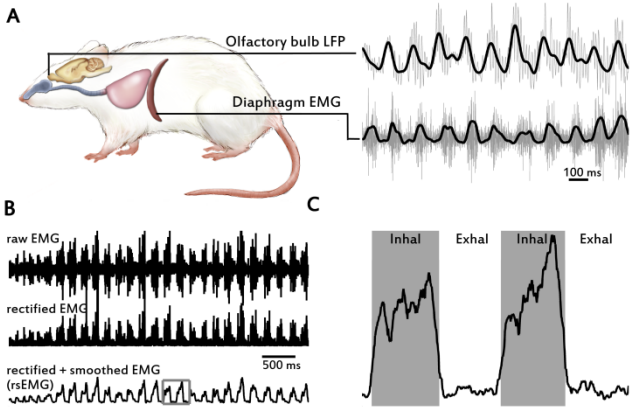


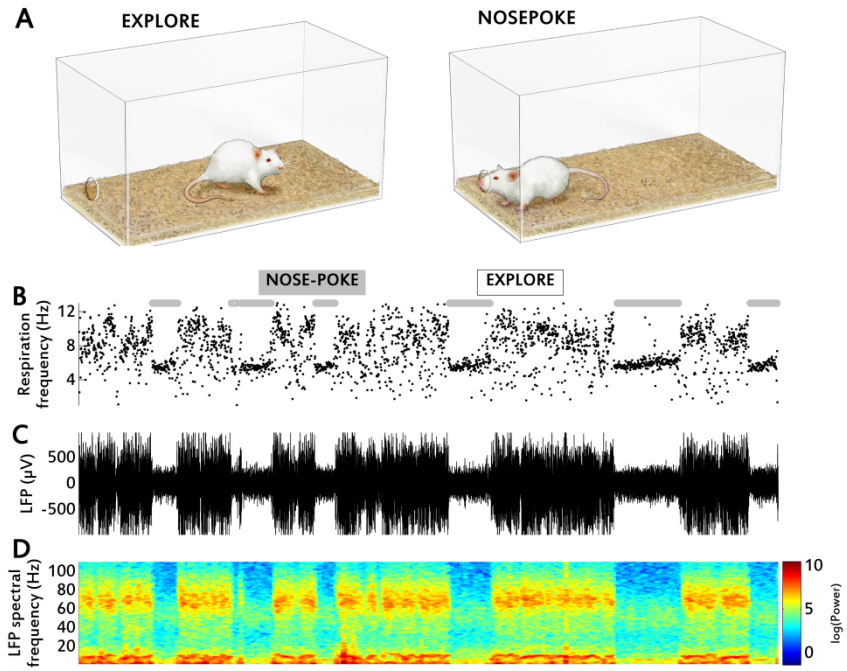
Individual pyriform cortex pyramidal cells spike in response to a few input mitral cell spikes summated in a short time window (~10 ms)

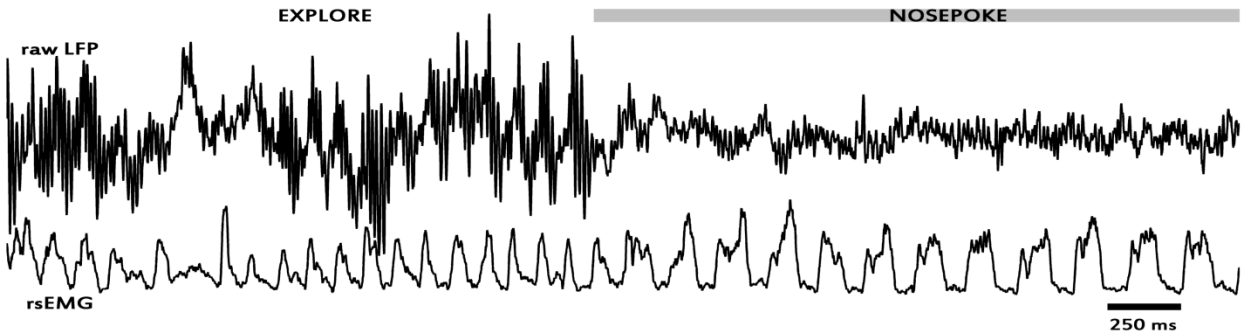
Franks and Isaacson, *Neuron* 2006

Behavior modulates oscillations

Daniel Rojas-Líbano



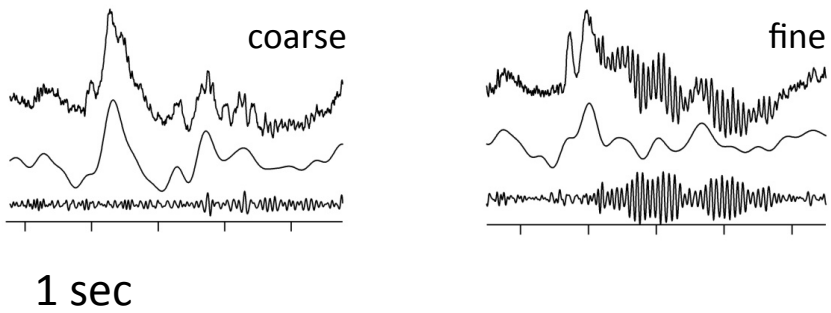


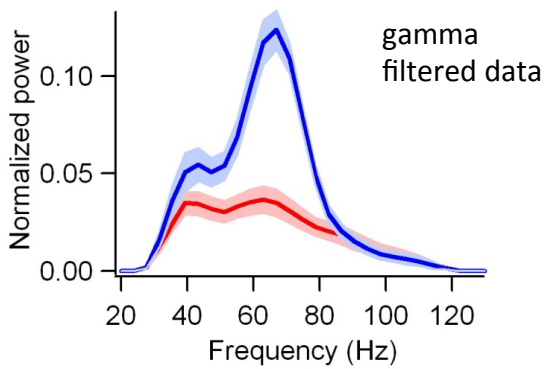


Rojas-Líbano et al.,
Front Behav Neurosci 2014

Behavioral context modulates oscillation power and type

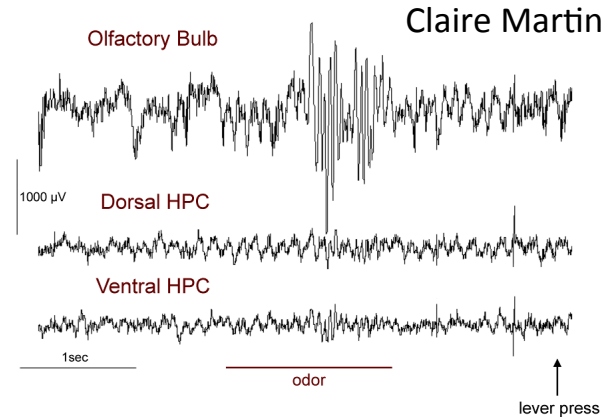
Jennifer Beshel

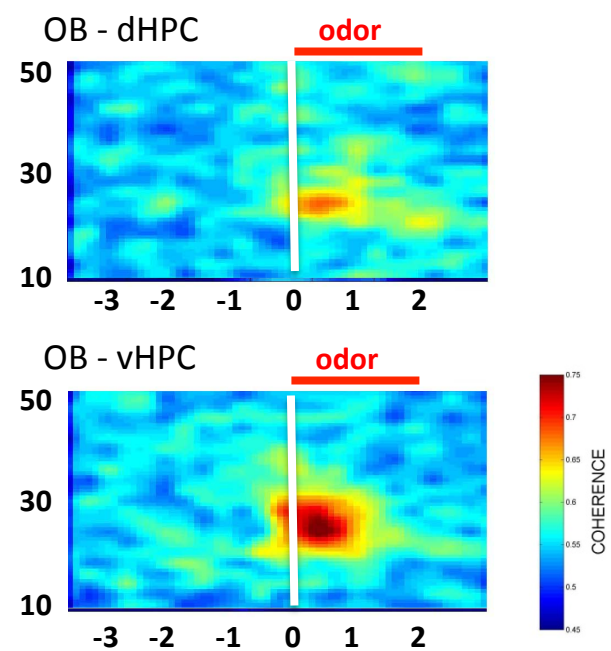




Beshel et al., *J Neurosci* 2007

Claire Martin

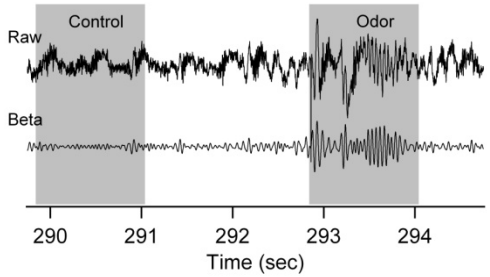


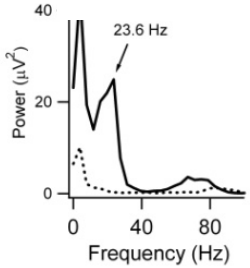


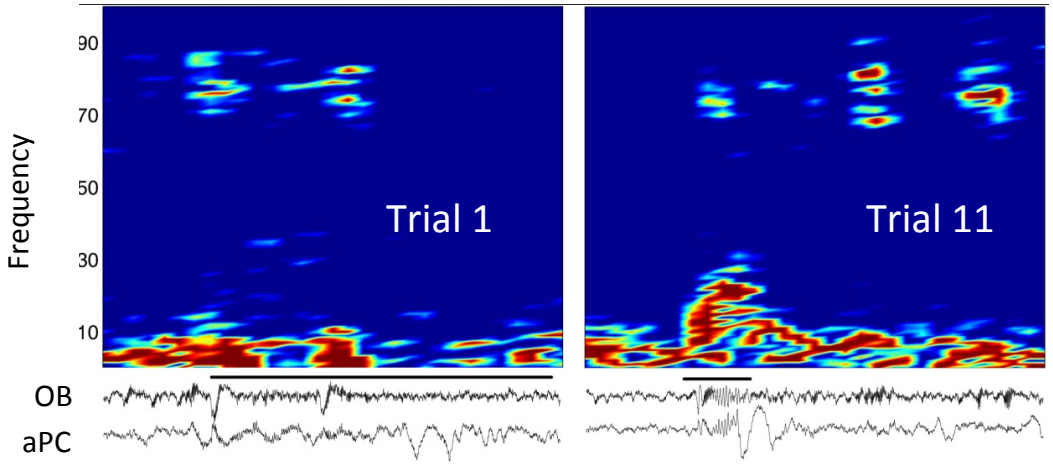
Martin et al., *J Neurophysiol* 2007

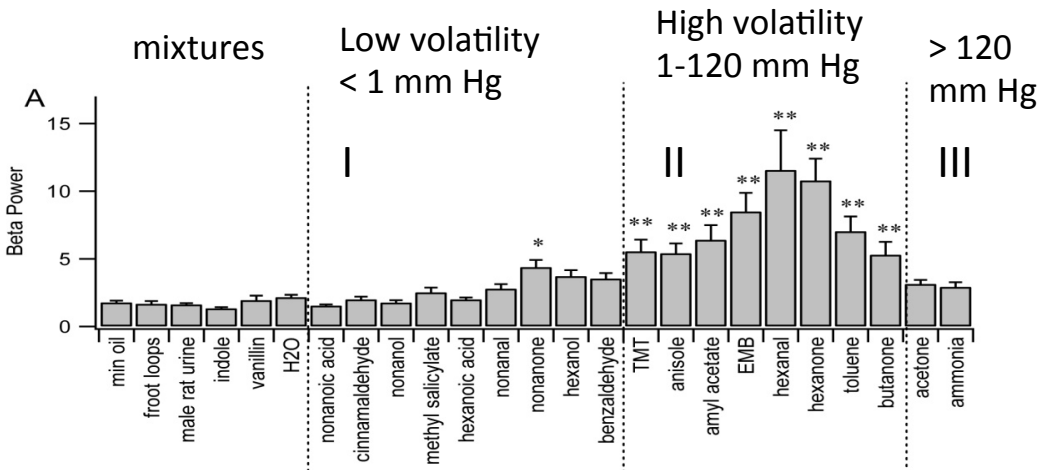
Beta oscillations, odorant volatility and sensitization

Catherine Lowry Franssen



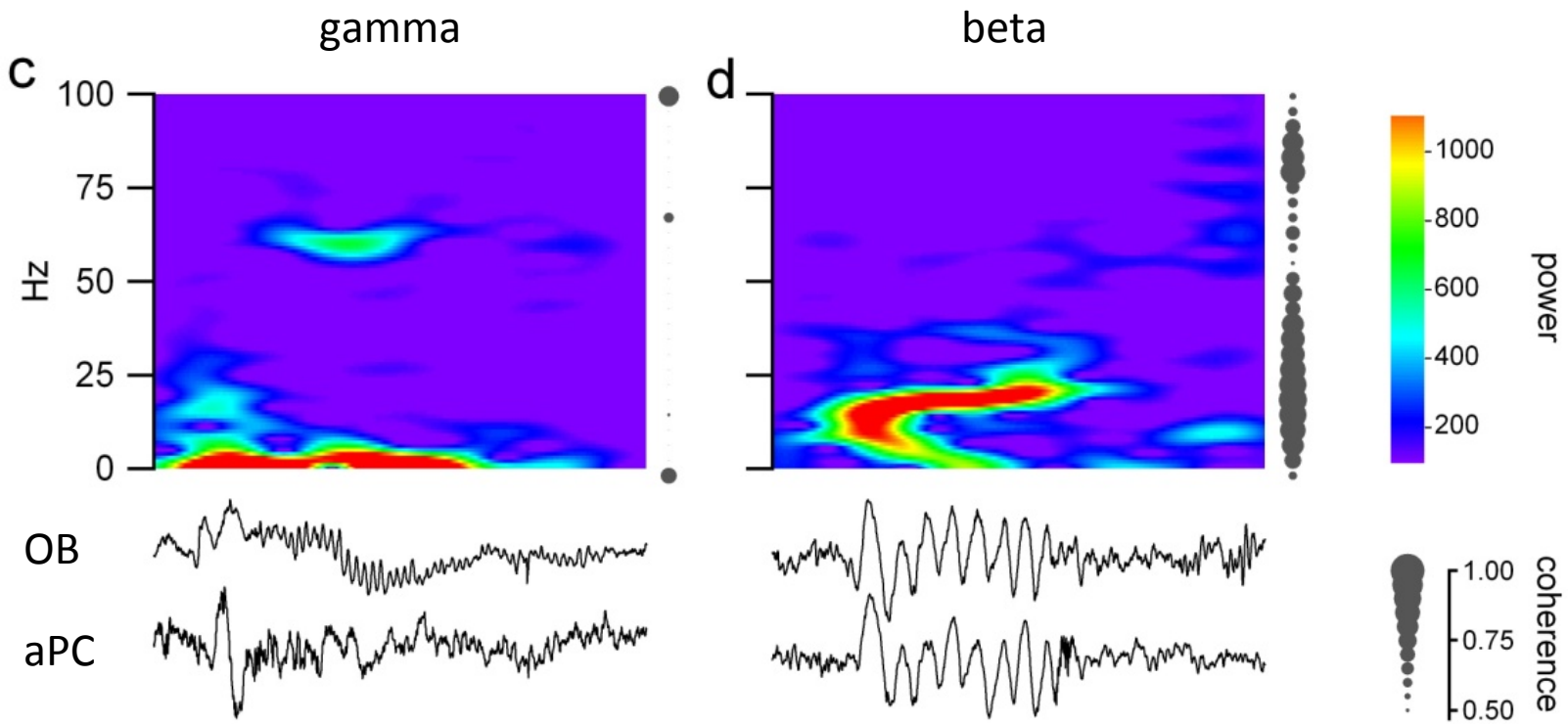






Lowry & Kay, *J Neurophys* 2007

More than just frequency differences

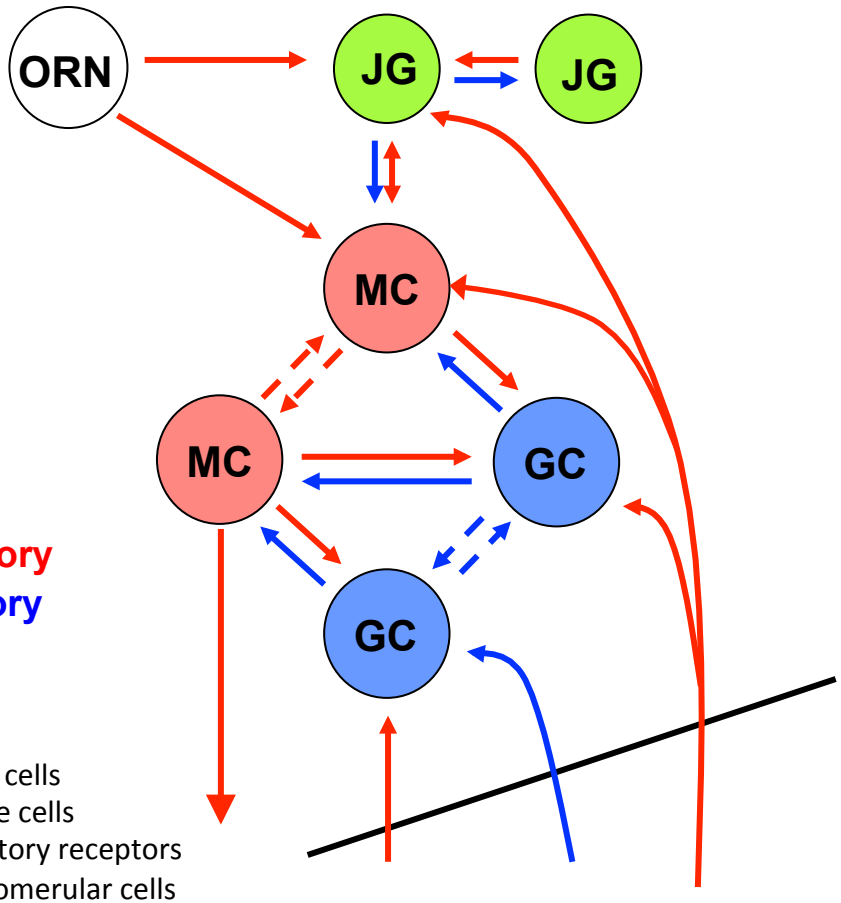


Without centrifugal input, gamma increases.

Without centrifugal input, beta disappears.

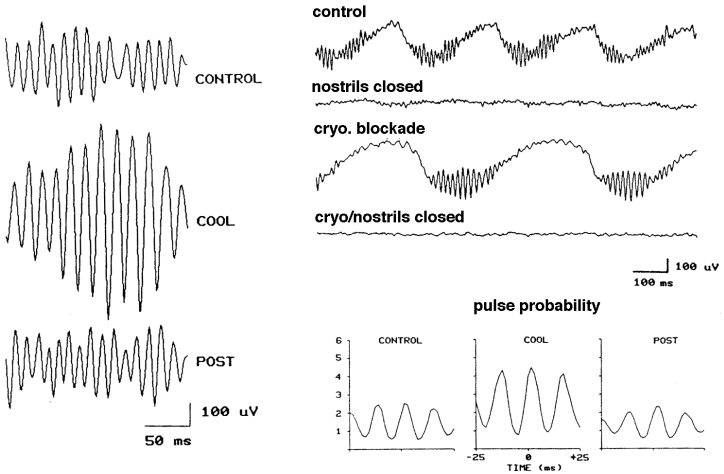
Kay et al., *TINS* 2009

More than just frequency differences



Excitatory
Inhibitory

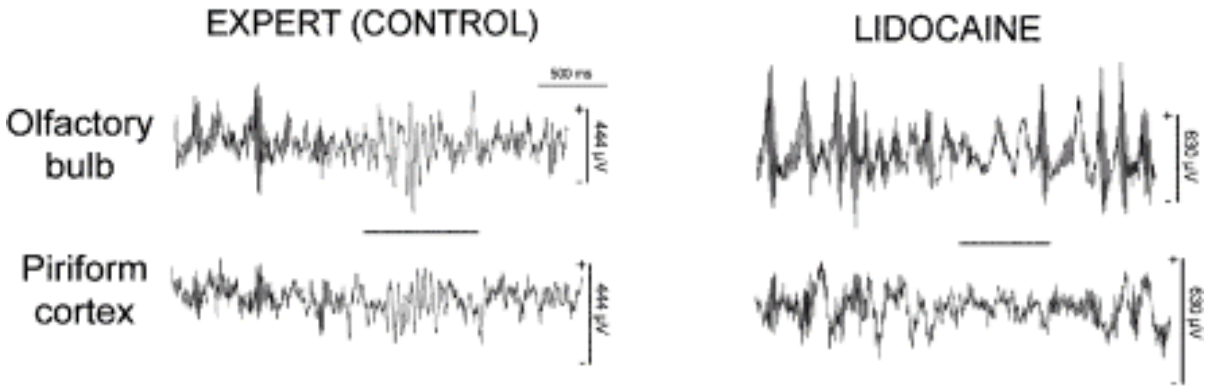
MC- mitral cells
GC- granule cells
ORN- olfactory receptors
JG- juxtaglomerular cells



Gray & Skinner, *Exp Brain Res* 1988

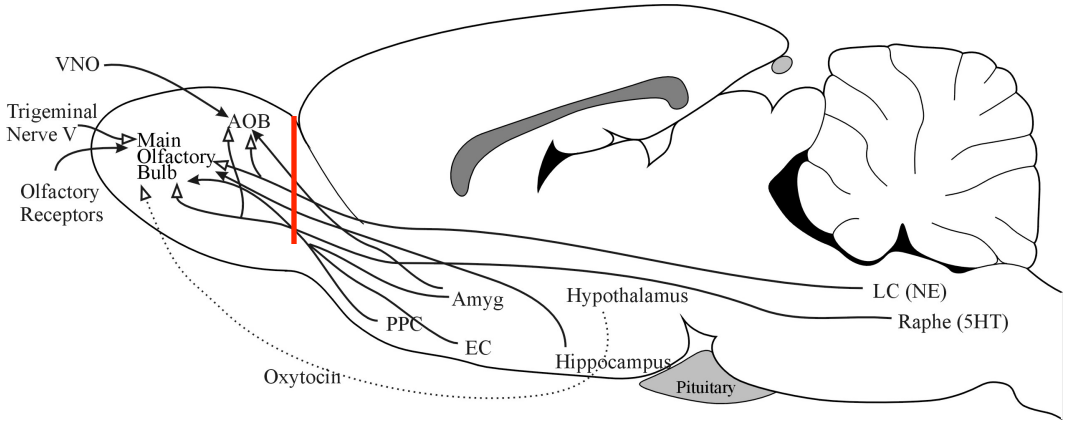
Fig. adapted from Freeman, 1975

Beta oscillations require an intact network



beta decreases
gamma increases

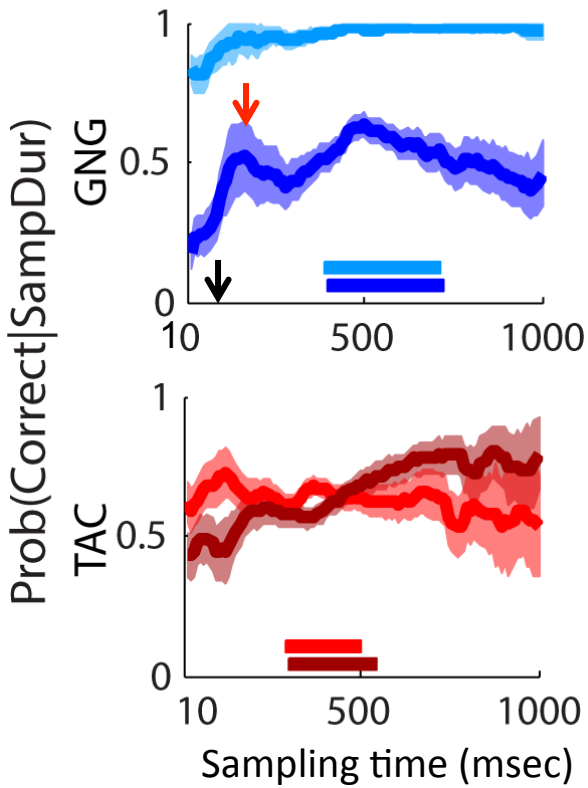
Martin et al., *Eur J Neurosci* 2006



Rats sample ~1 sniff longer for go/no-go than 2-alternative choice

Donald Frederick

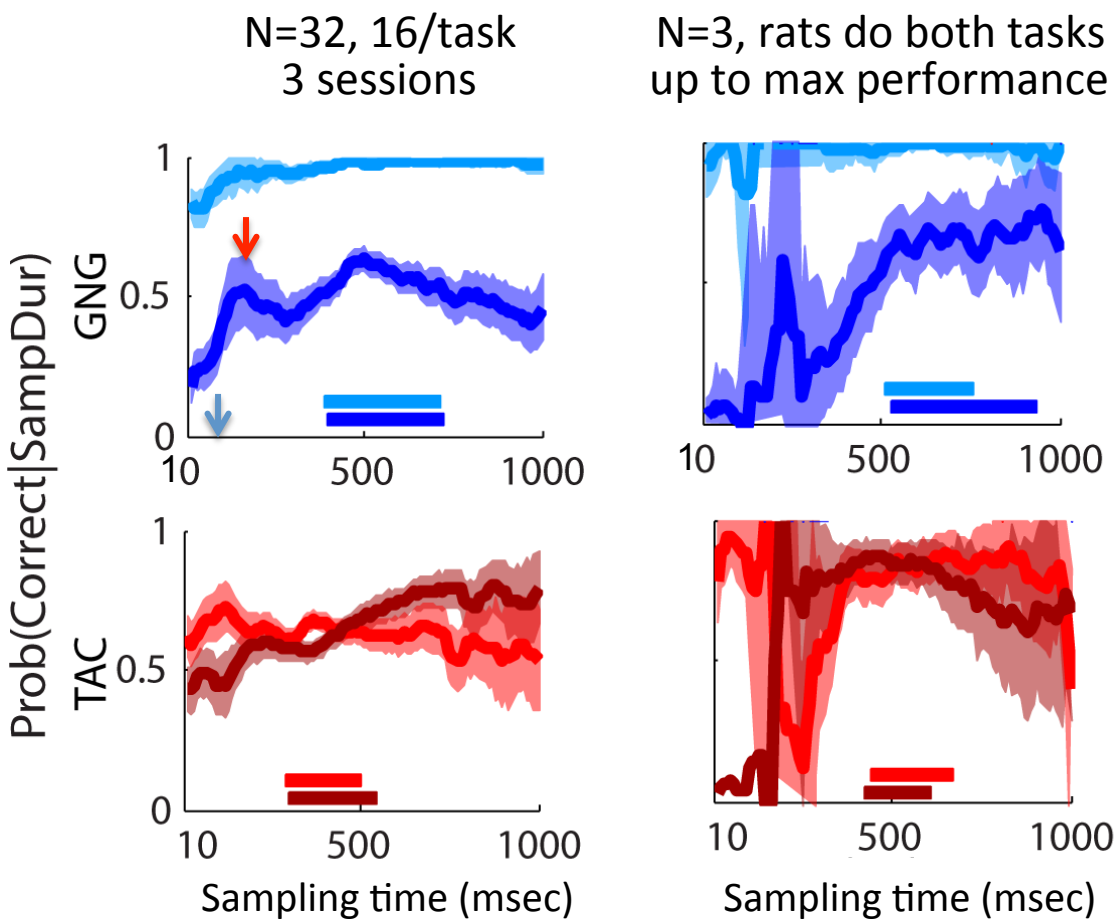
N=32, 16/task
3 sessions
150 trials/session



No differences in sampling times and performance at the end of training; differences emerge upon rule transfer.

8 odor sets varying in volatility and 2DG glomerular map overlap, including 'extreme' odor set. 3 sessions for each odor set.

Rats sample ~1 sniff longer for go/no-go than 2-alternative choice

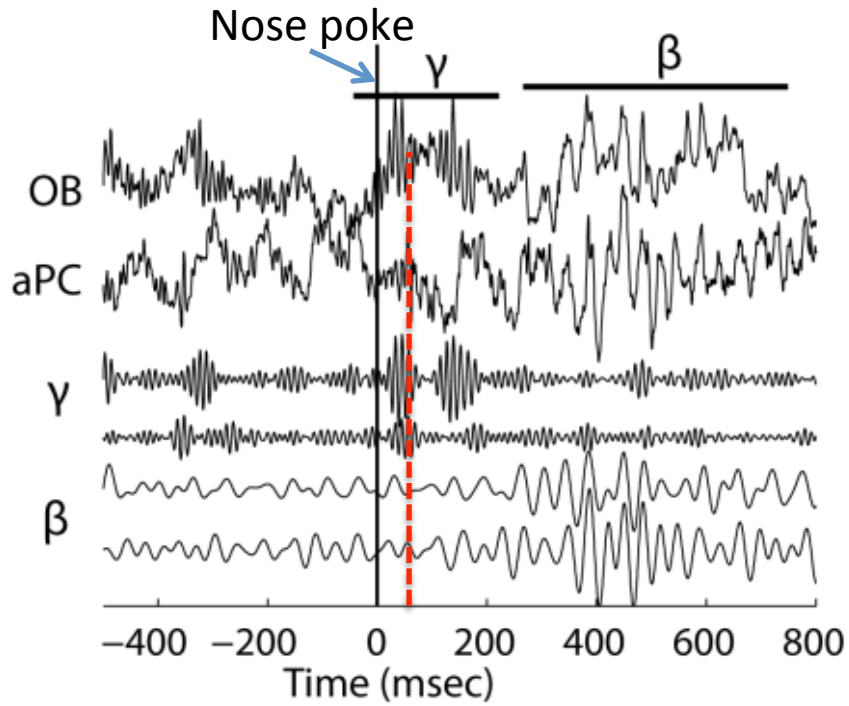


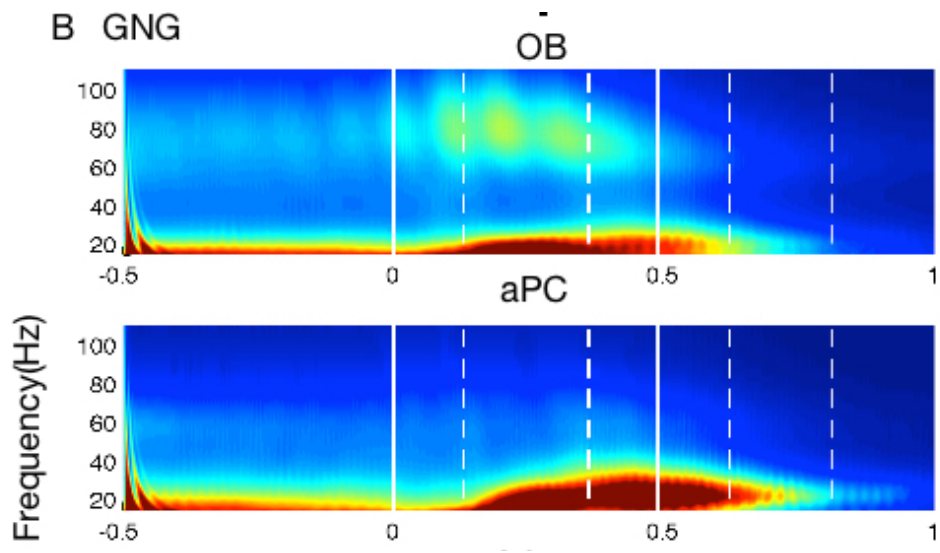
5 odor sets, 4 from first experiment one novel

No differences at the end of training; differences emerge upon rule transfer.

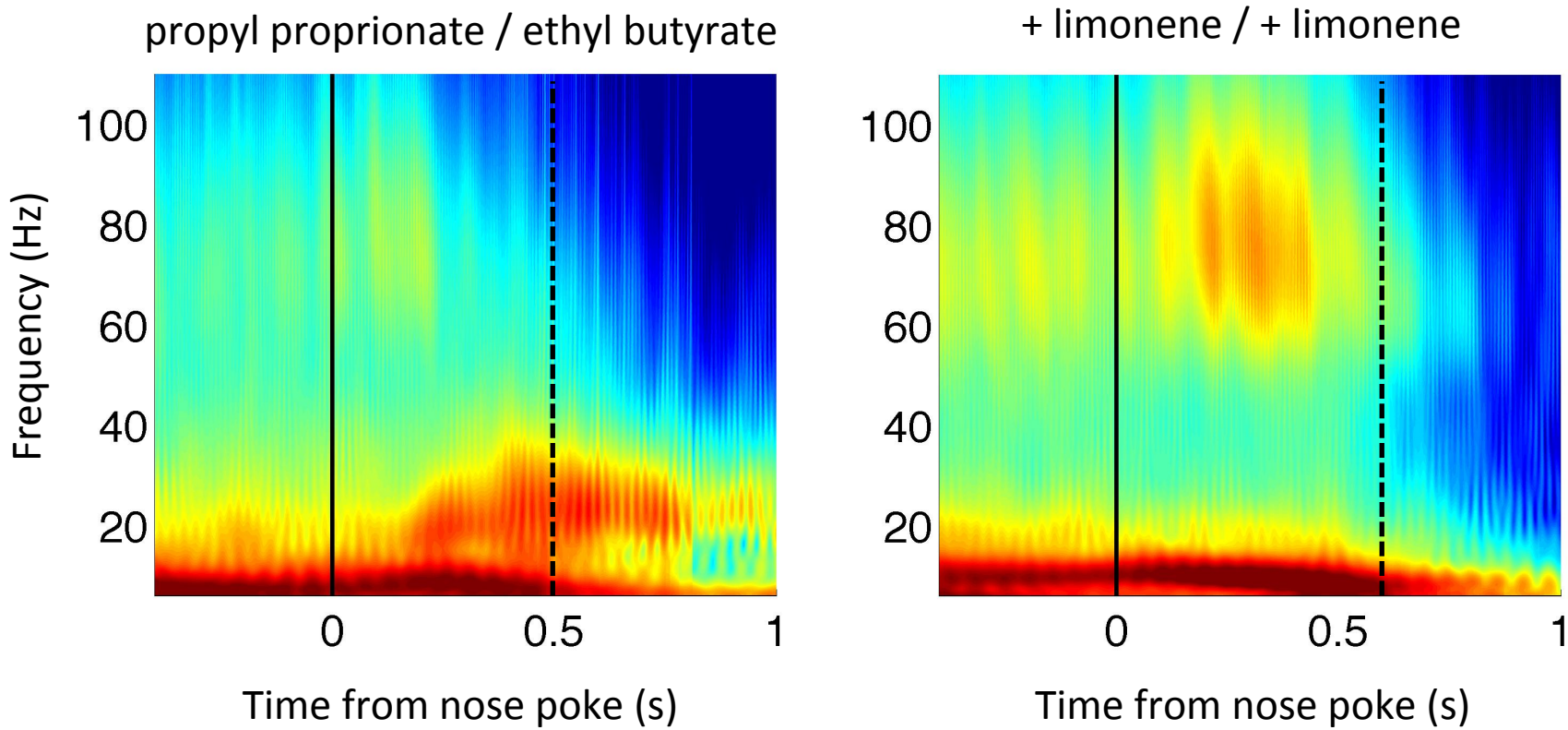
Stereotyped sequence of oscillatory states:

2-4 sniffs of gamma followed by beta oscillations at >250 ms





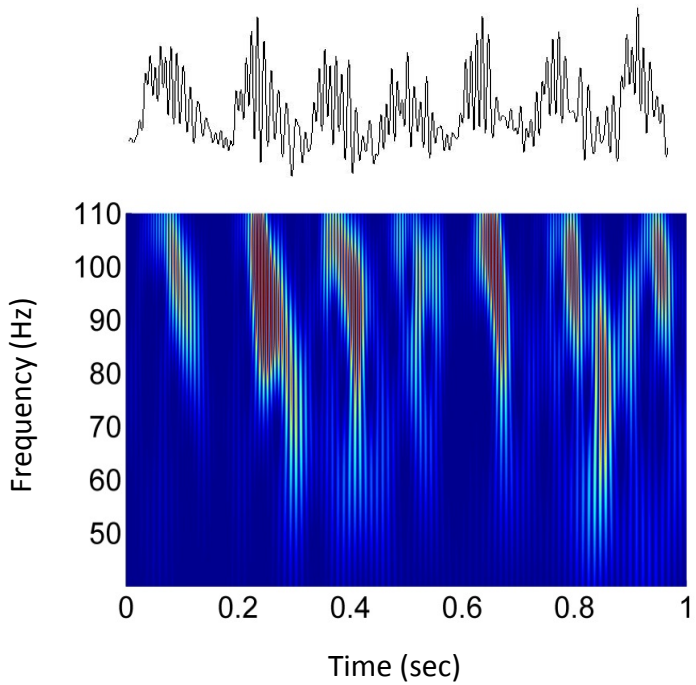
Beta and gamma modulated by odor, task, difficulty

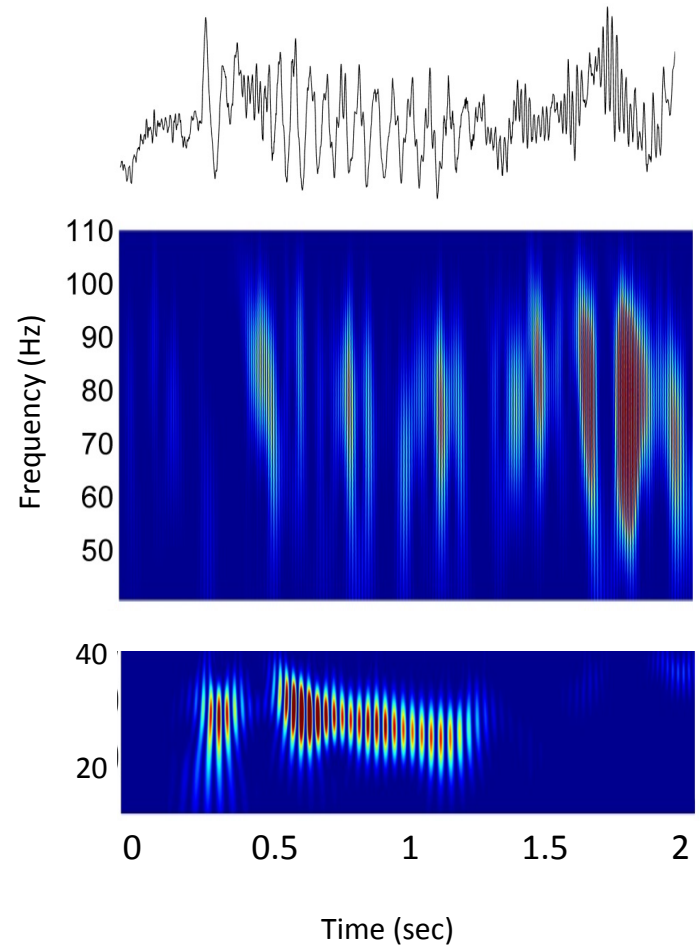


Rats manipulate the dynamics (flow) of the first 2 sniffs to target specific odors.

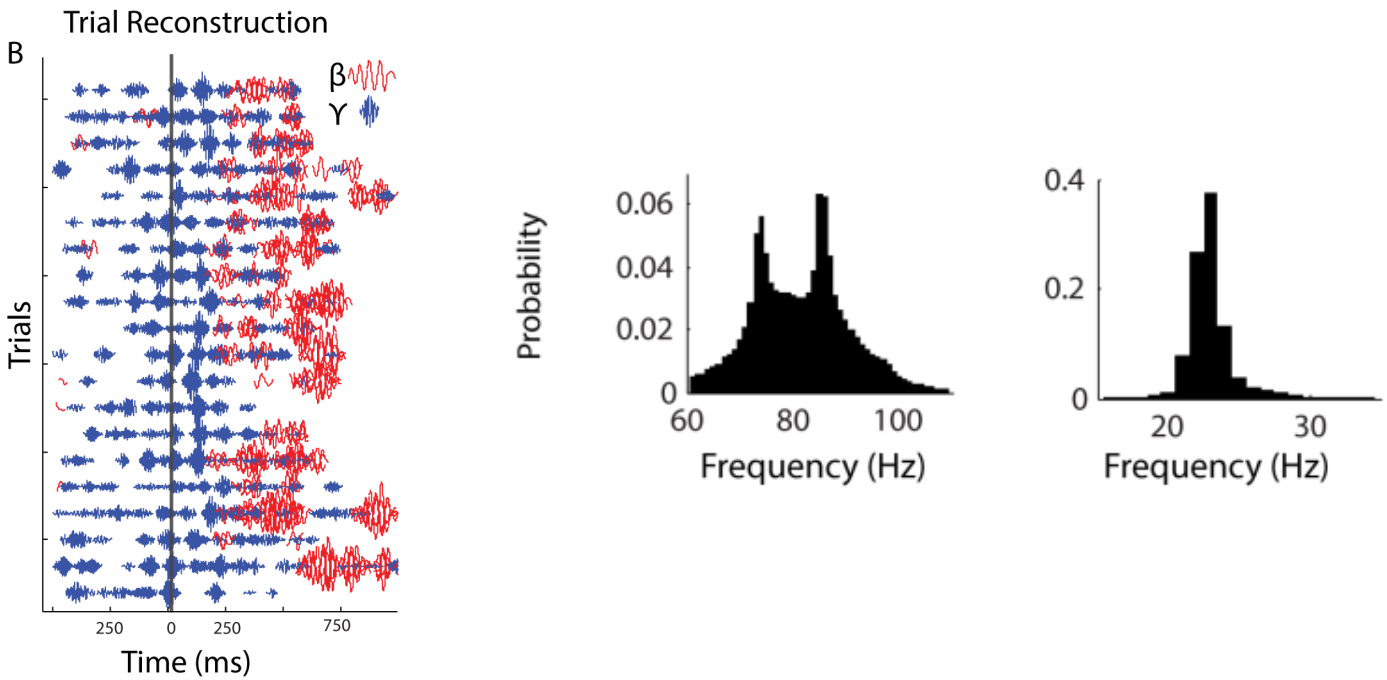
Rojas-Líbano and Kay, *J Neurosci* 2012

Identifying and extracting gamma and beta bursts





Gamma and beta in time and frequency

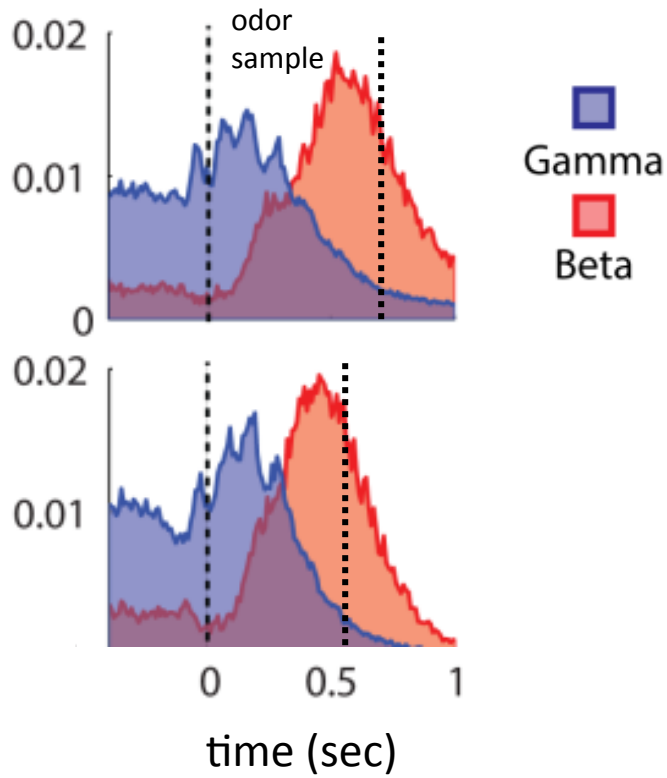


Burst onset histograms show temporal precision

Rats doing both tasks

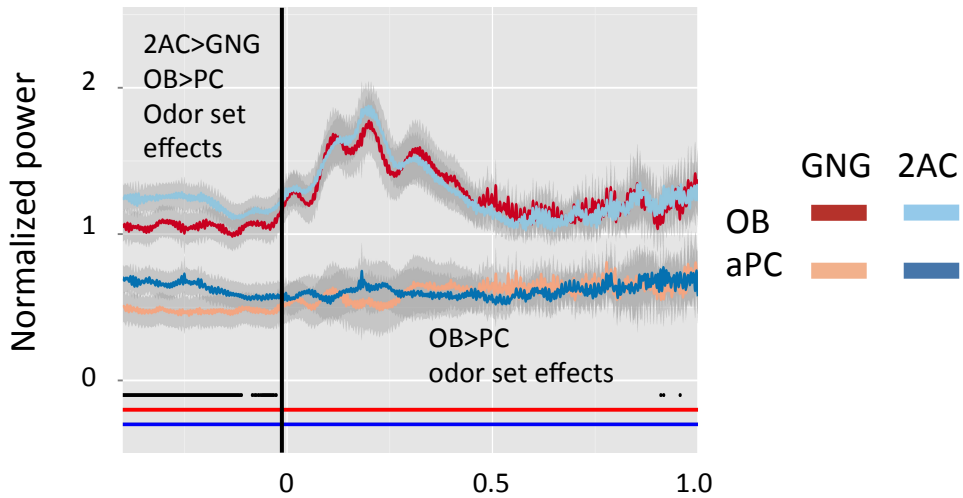
go/no-go

2-alternative choice

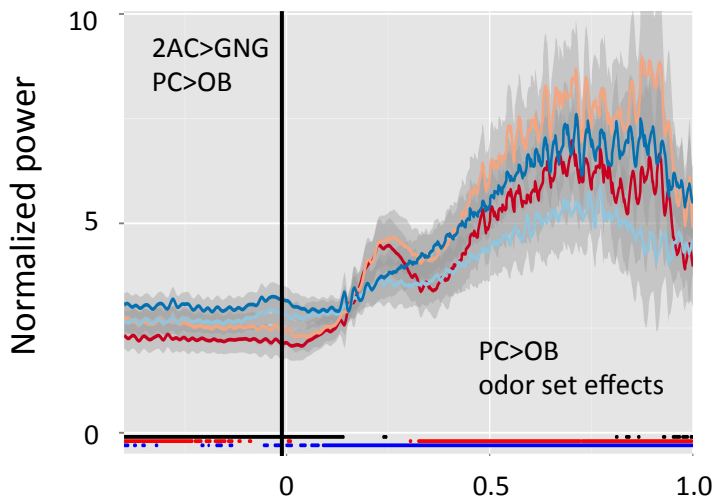


Gamma and beta dominate in different behavioral epochs

Gamma power is elevated during initial odor sampling



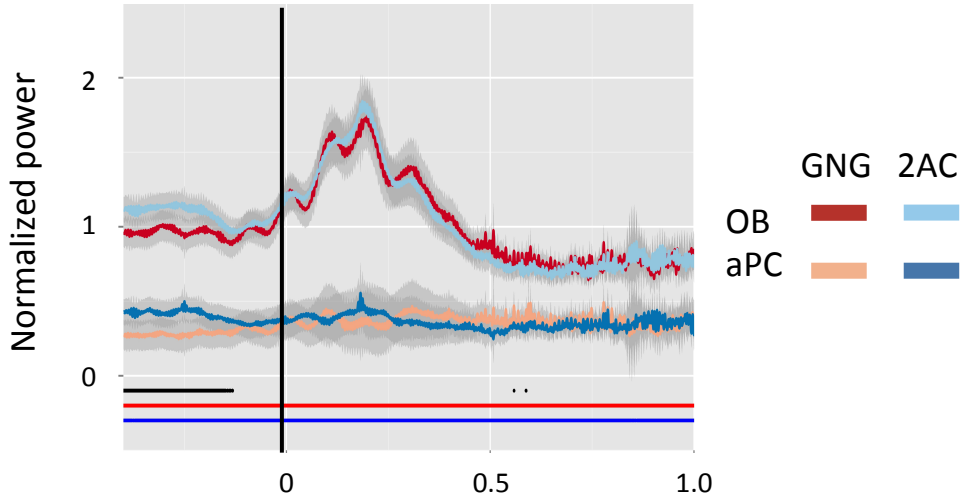
Beta power is elevated after ~250 msec



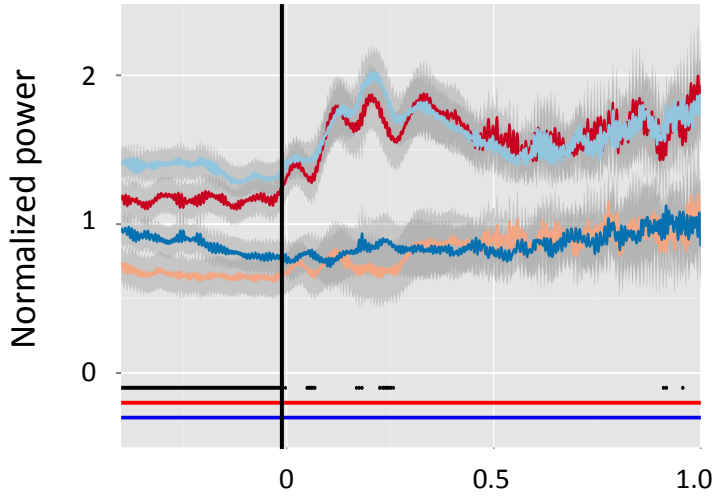
Results of GLS analysis

Fast and slow gamma dominate in different behavioral epochs

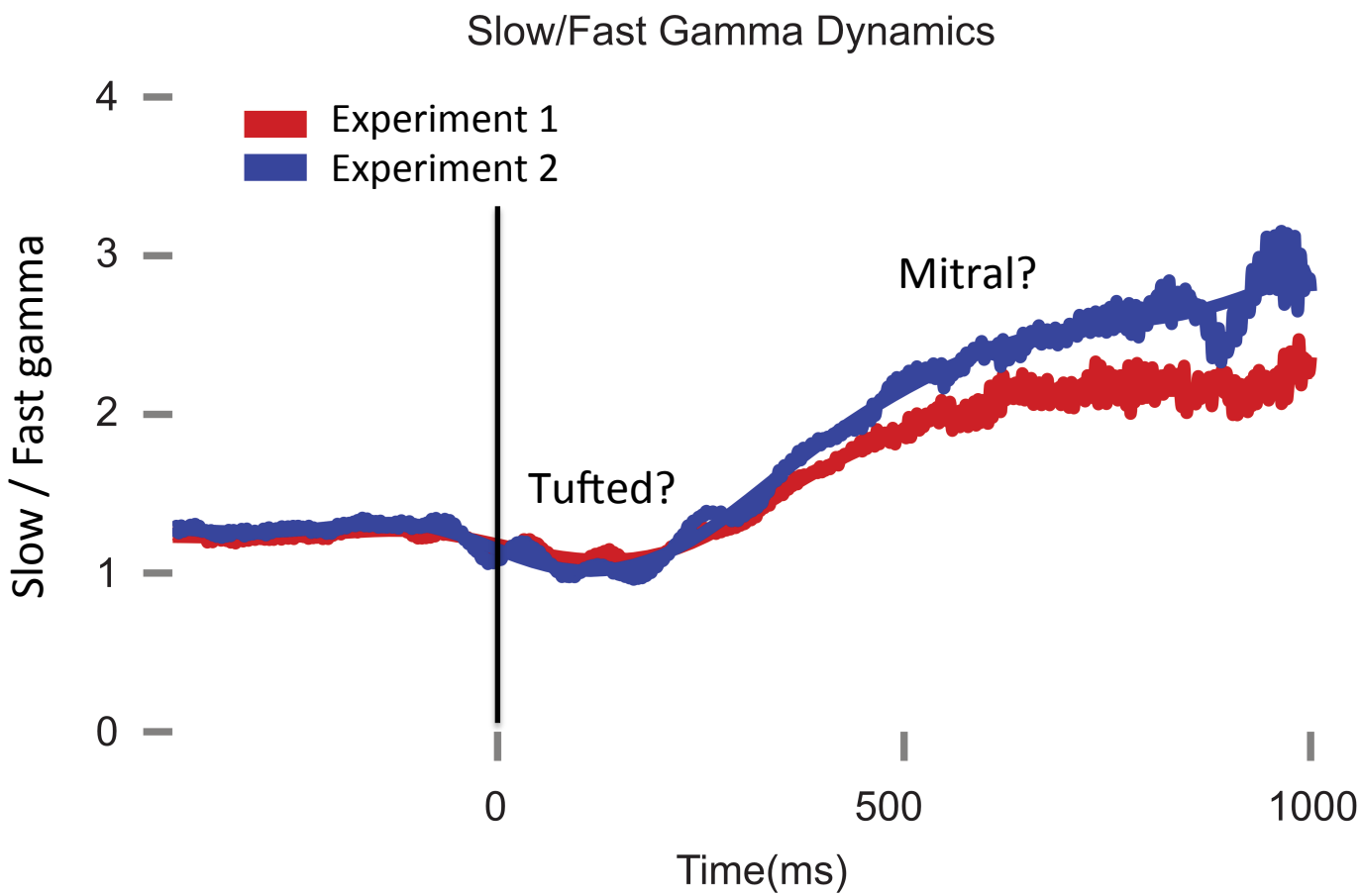
Fast Gamma (80-100 Hz; presumed tufted cells)



Slow Gamma (60-80 Hz; presumed mitral cells)

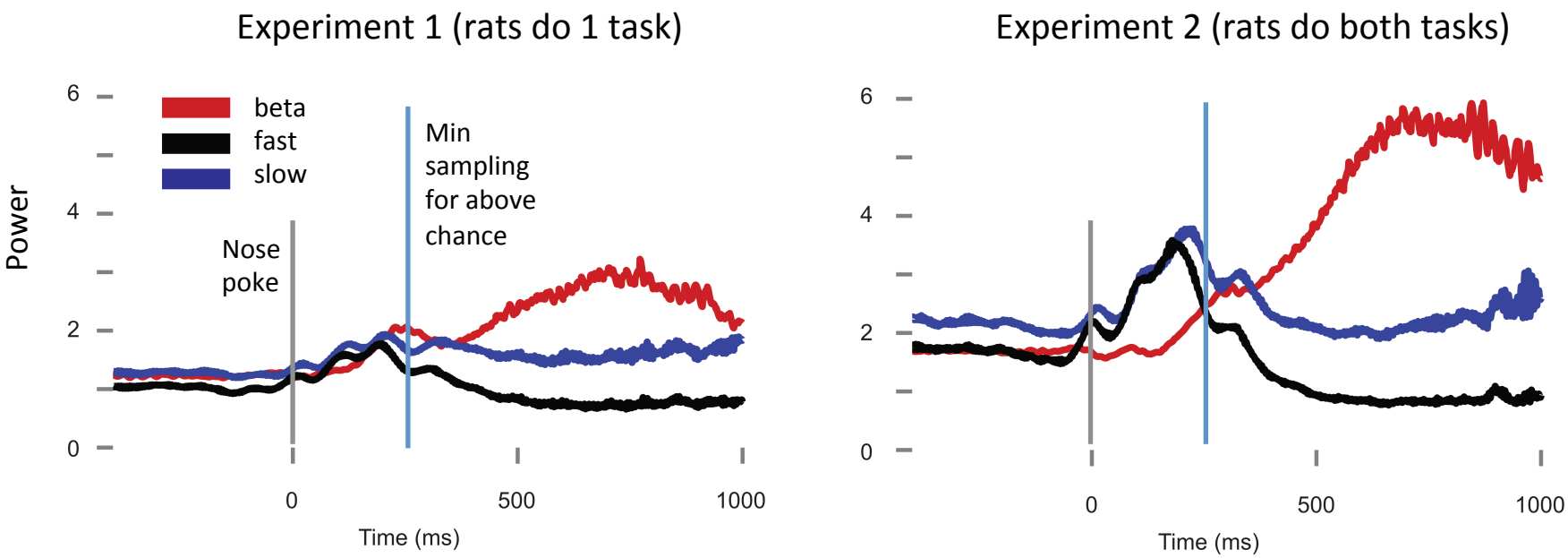


Fast and slow gamma dominate in different behavioral epochs



2 curves from 2 experiments (between, n=8, and within, n=3, subjects)

Temporal relationships among all 3 frequency bands



Beta scaled by 0.5 for display

Summary

- Rats sample ~1 sniff longer in the GNG task
- Beta oscillations begin after ~250ms of sampling and are tied to the exit from the odor port
- First 2-3 sniffs show strong gamma
- Fast gamma is strongest in the first 2-3 sniffs (tufted cells?), when gamma is strongest
- Slow gamma dominates after the first few sniffs (mitral cells?), when beta is strongest
- Fast gamma and beta appear to supplant each other