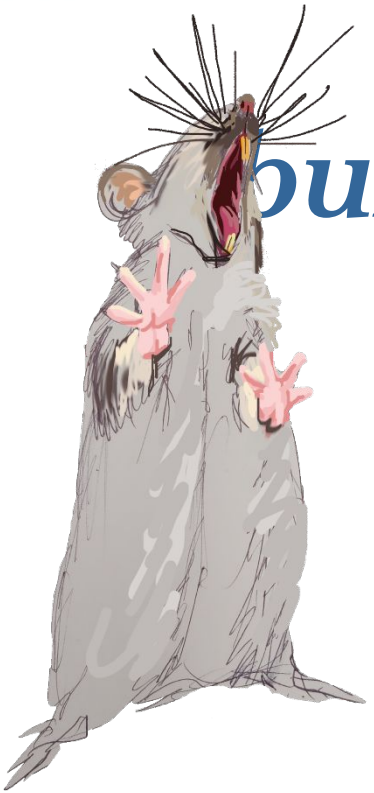
The Cortico-Amygdalar interaction dynamics underlying taste perception & action



buzar Mahmood

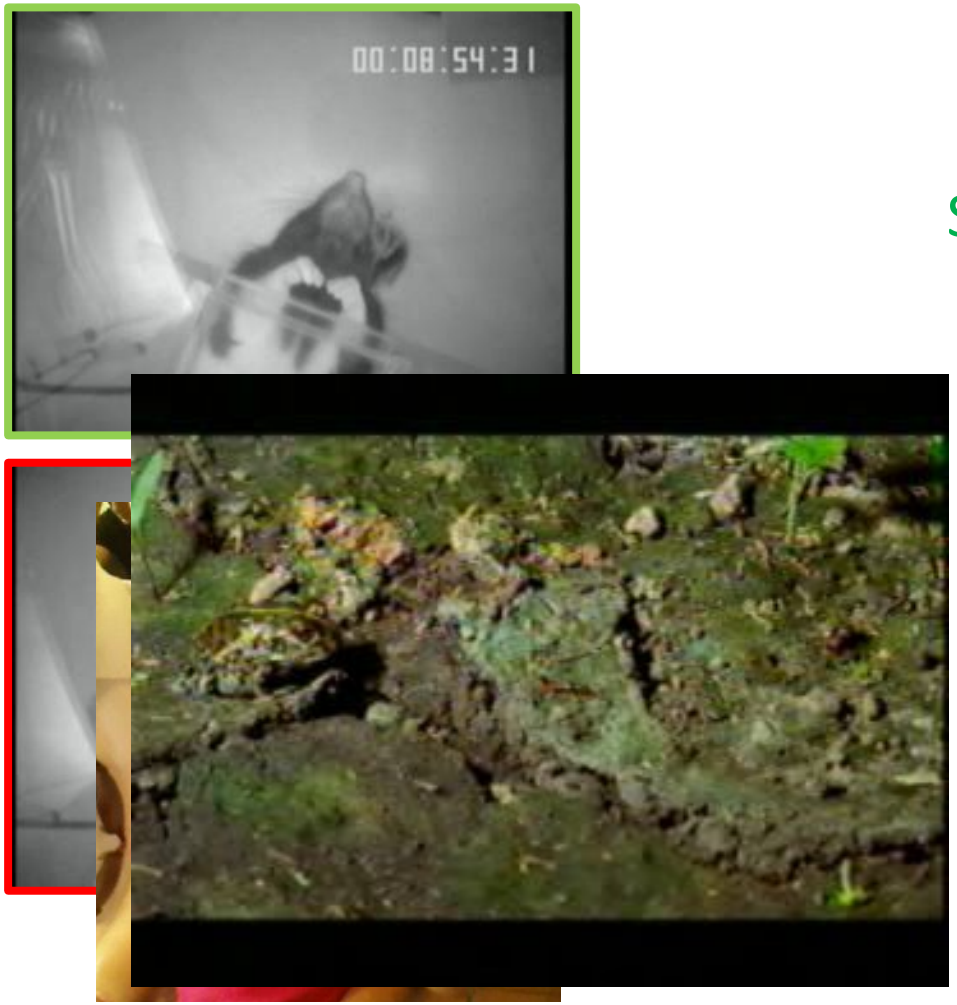
Katz Lab

The Benjamin & Mae Volen National Center for Complex Systems

Brandeis University

Illustrations courtesy of Katie Kimbrell

The inevitable sensorimotor transformation of taste information



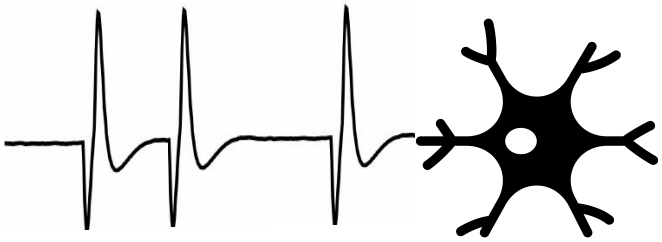
Sweet or salty –
licks (yum!)

Vs

Bitter or sour –
gapes (yuck!)

Grill-Spector & Ostad, '88
Rosenstein & Oster, '88

A process that unfolds through time and within networks



What we believe … and what I will show:

1) Time matters in neural taste processing.

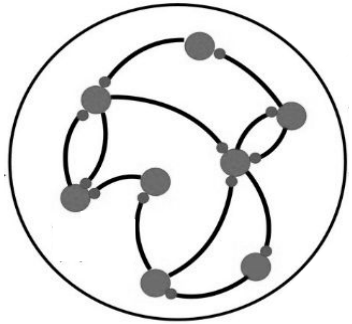
   - cortical taste responses evolve across 1-1.5 seconds, and this evolution is meaningful.

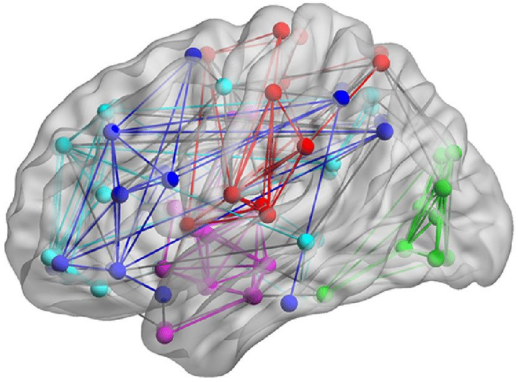
2) Neural ensembles work together to process tastes.

   - single-trial dynamics are coherent across ensembles and nonlinear, and the coherent nonlinearities drive behavior.

3) So do brain regions.

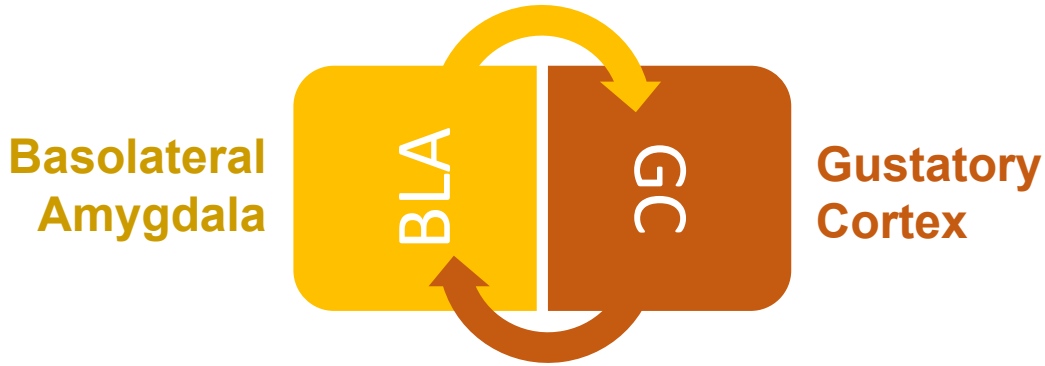
   - amygdala couples with cortex into a single processing unit, enabling these nonlinear dynamics.





RECURRENT CONNECTIVITY IN THE TASTE CIRCUIT

Stone et al. 2011
Haley et al. 2016

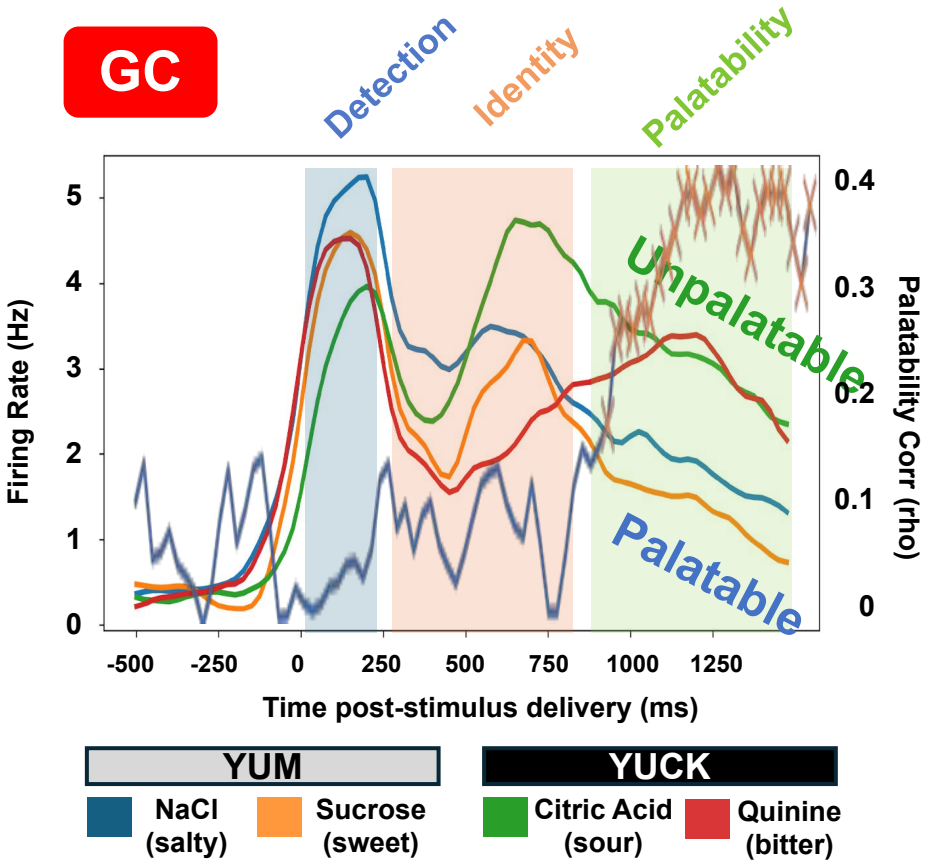


Bielavska and Roldan 1996
McDonald 1998

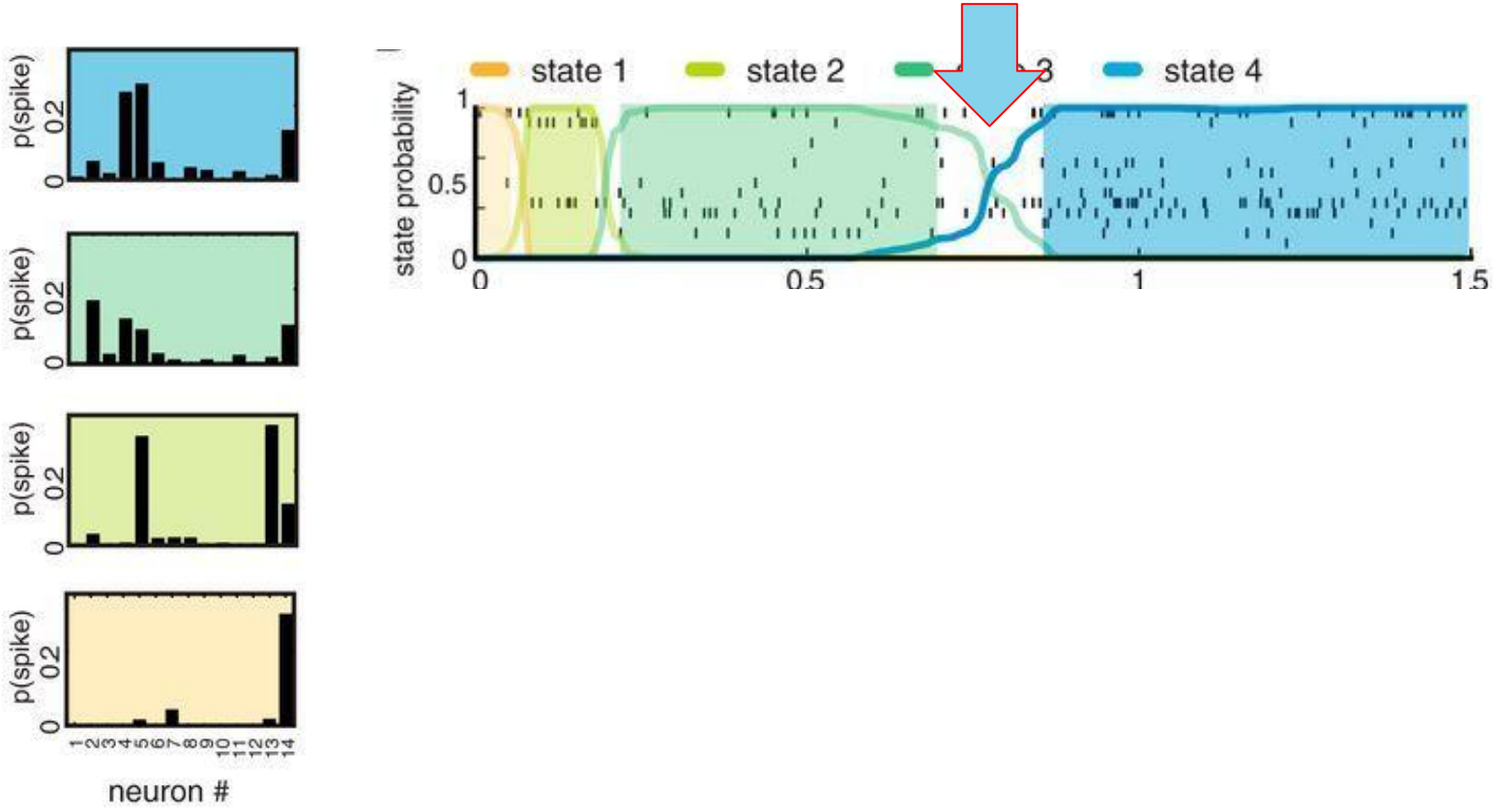
Figure adapted from Carleton et al. 2010 and Merlo et al. 2015

- IOC methods
- Not quote ethologically valid, but I'd be happy to discuss why we expect the results we see here to be representative of the taste processing

GC POPULATION ACTIVITY EVOLVES AS STATES

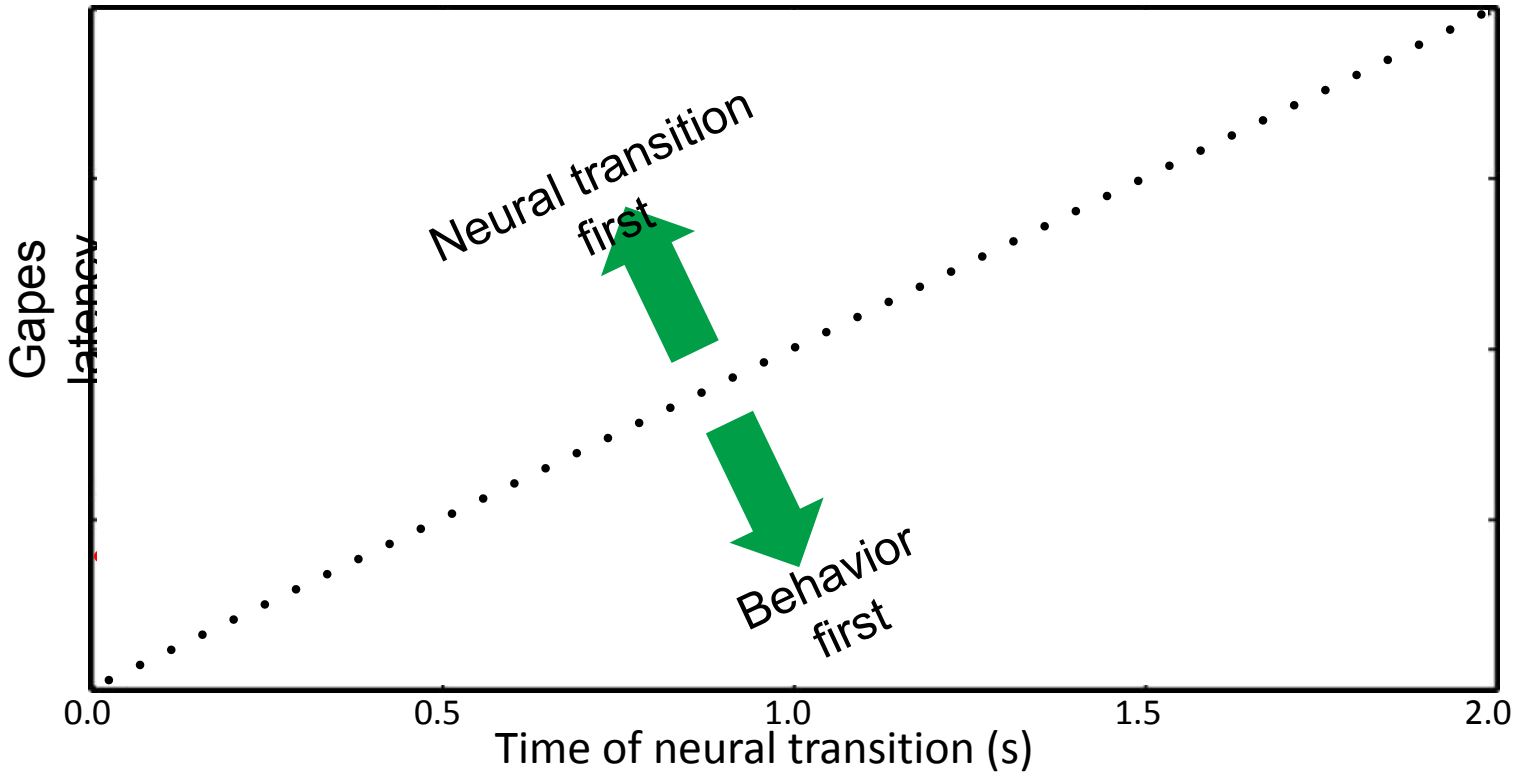


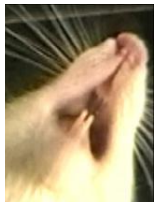
A process that unfolds through time and within networks



Sadacca *et al*, 2016

Ensemble state transitions reflect taste decision-making

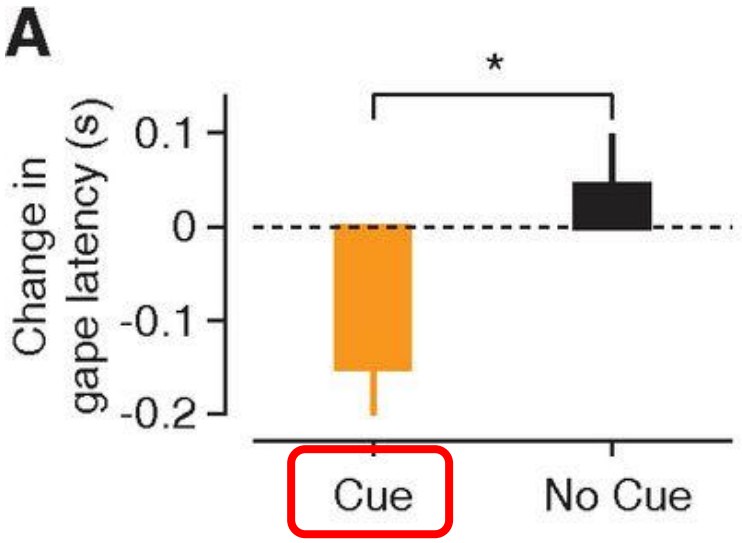




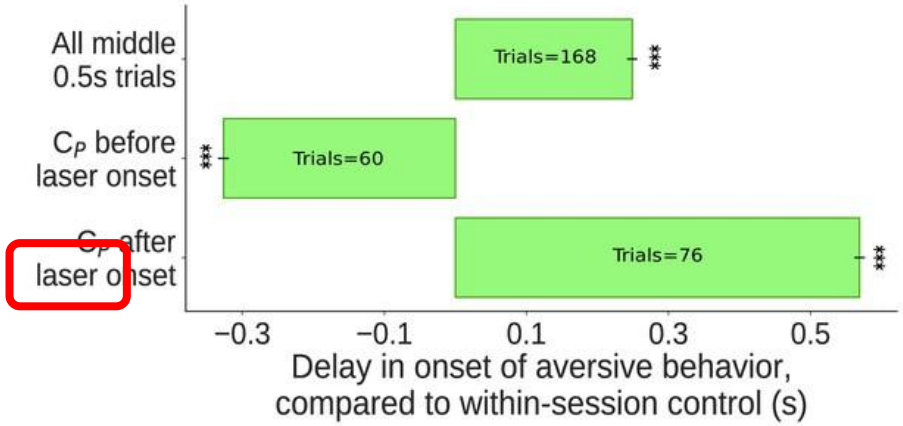
Sadacca *et al*, 2016

GC is causally involved in initiation of behavior

Li et al. 2016



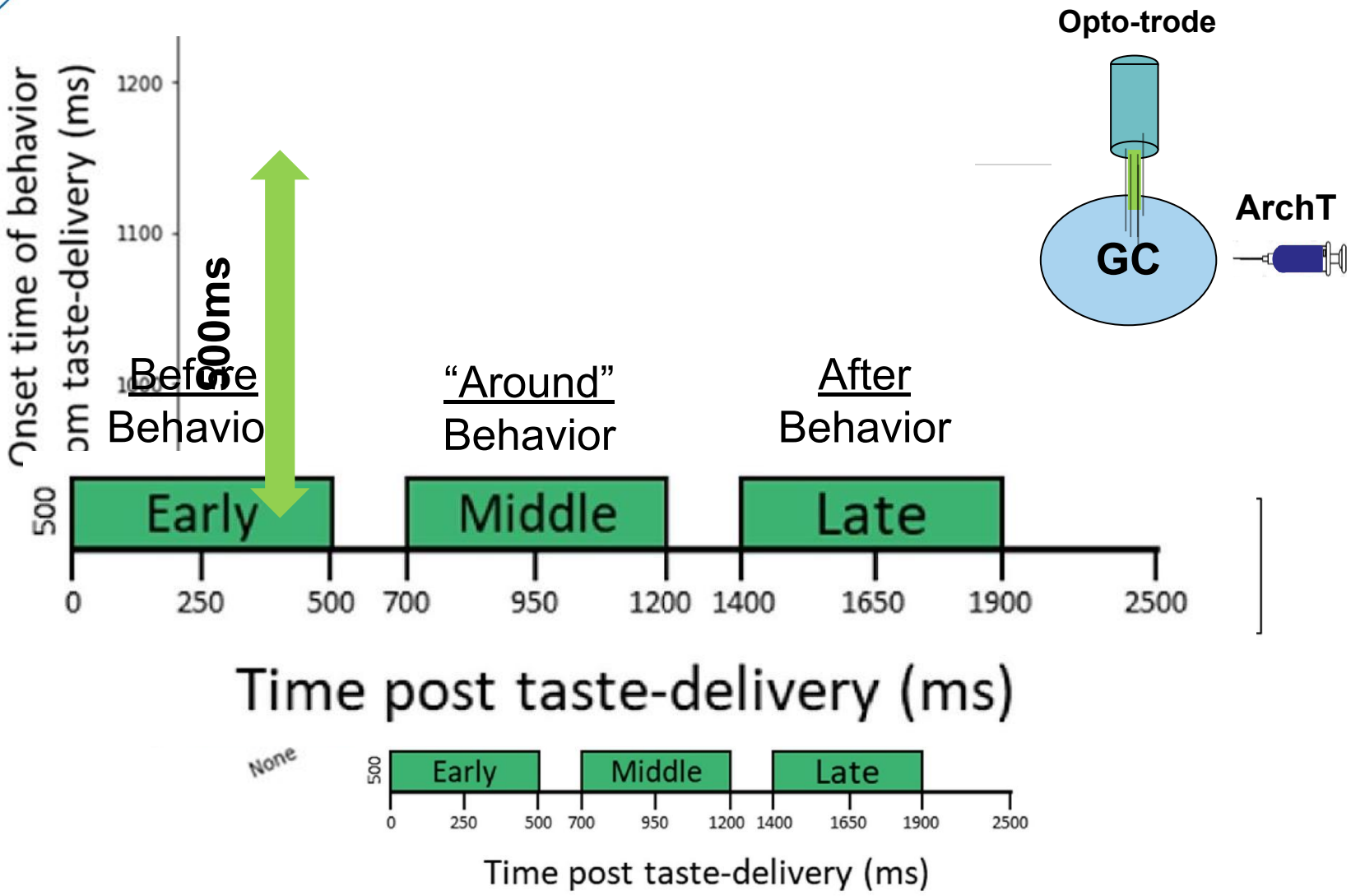
Mukherjee et al. 2016



You might decide to just skip Li et al, if you need a little time. And by the way: the figure that you need was not actually in the paper *per se*!

Yes: use clearer panel. You might also want to make it full-page.

GC is causally involved in initiation of behavior



Mukherjee *et al*, 2019

VERY UNLIKELY BLA IS NOT COORDINATED WITH GC

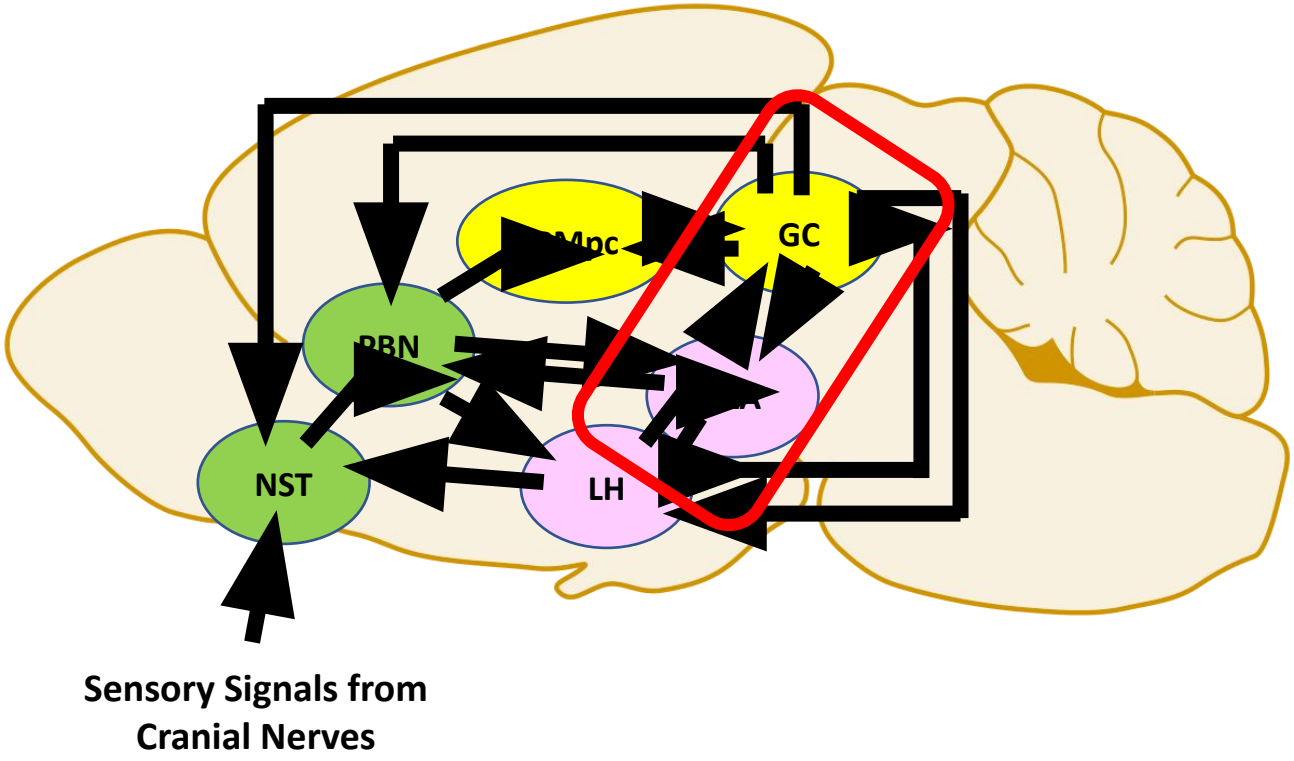
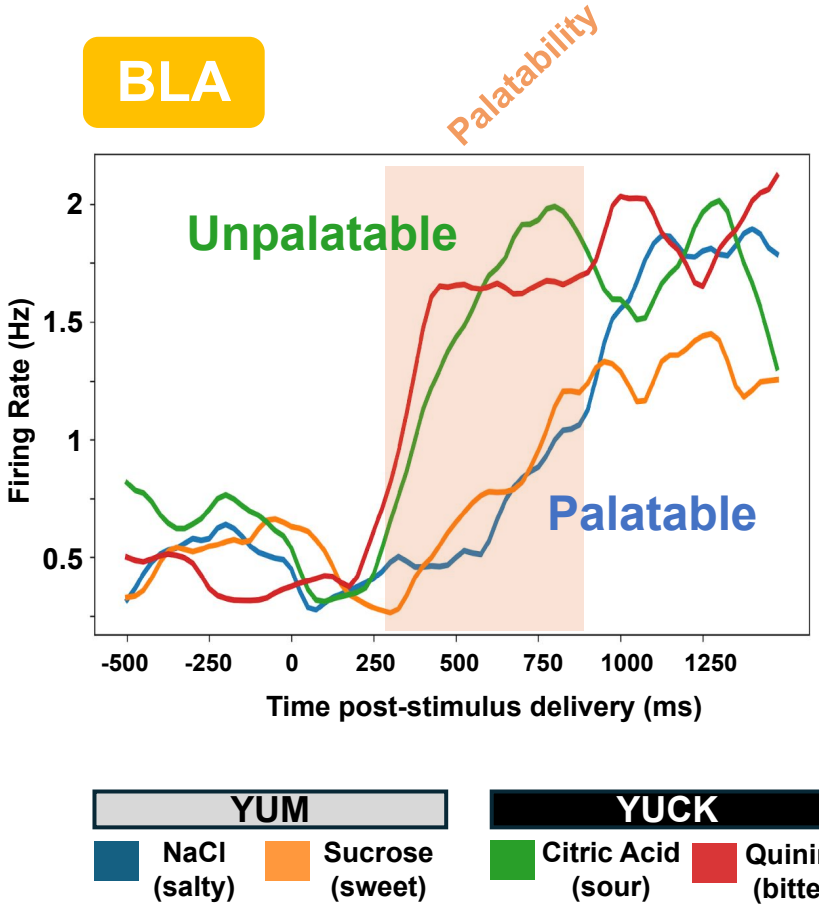
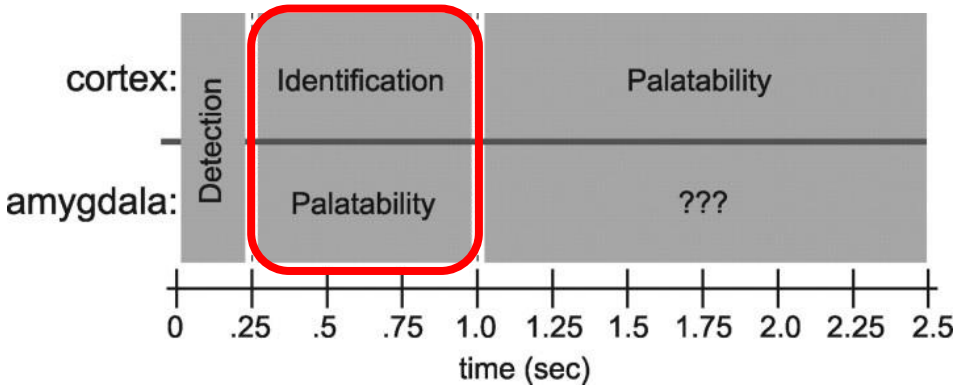
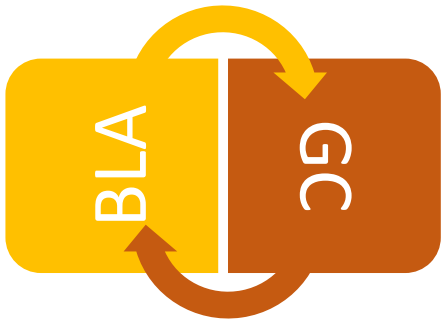


Figure adapted from Carleton et al. 2010 and Merlo et al. 2015

BLA AND GC SIMILARITIES IN AVERAGE ACTIVITY



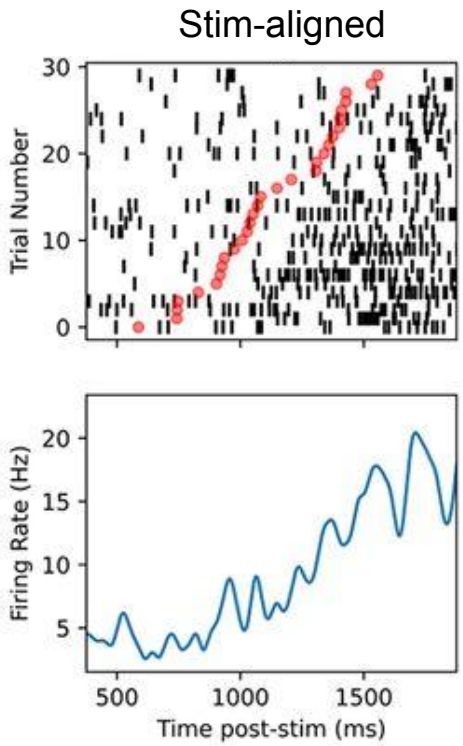


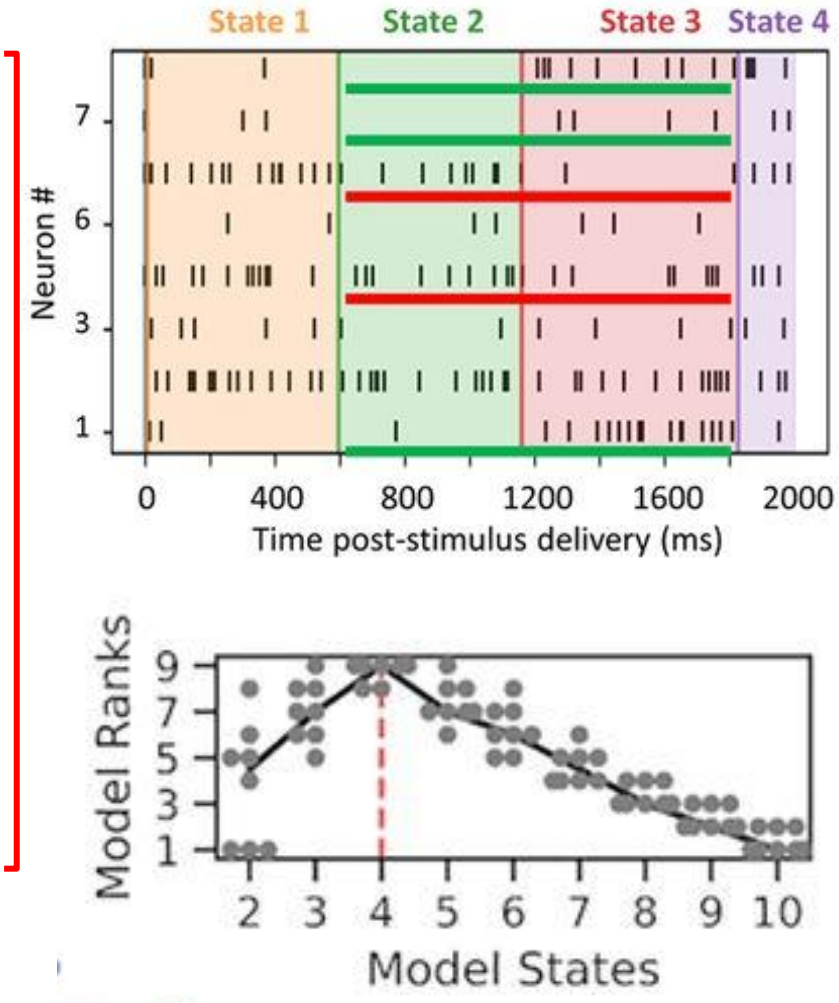


PREDICTIONS #1

1. BLA population activity will evolve as a sequence of states
2. BLA-GC transition #2 will be coordinated

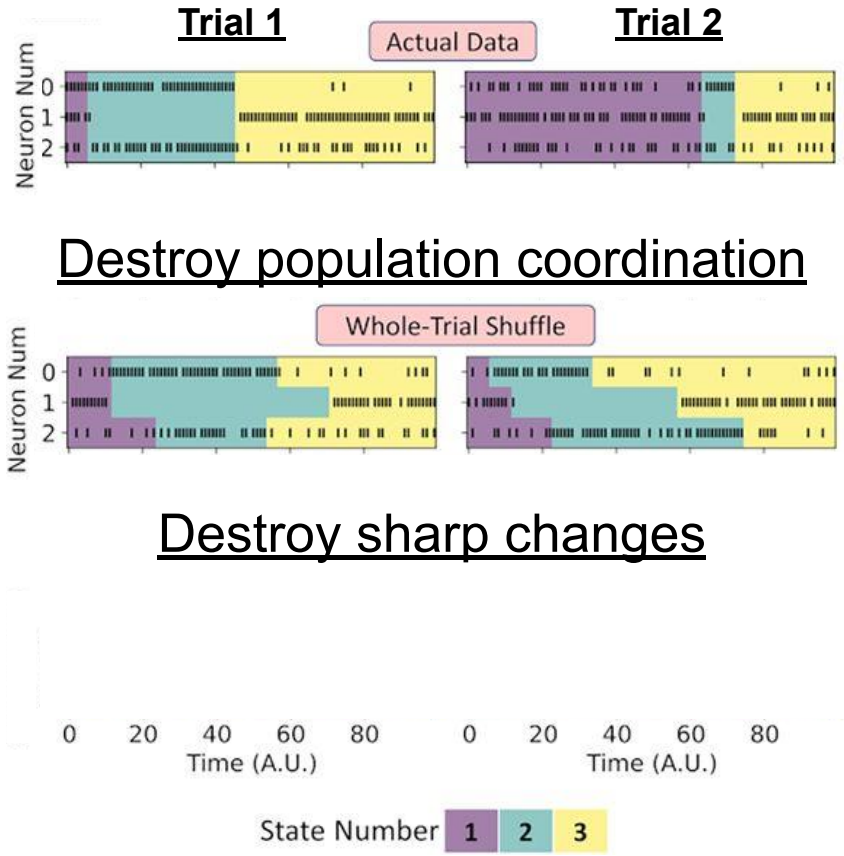
STATES IN BLA POPULATION ACTIVITY

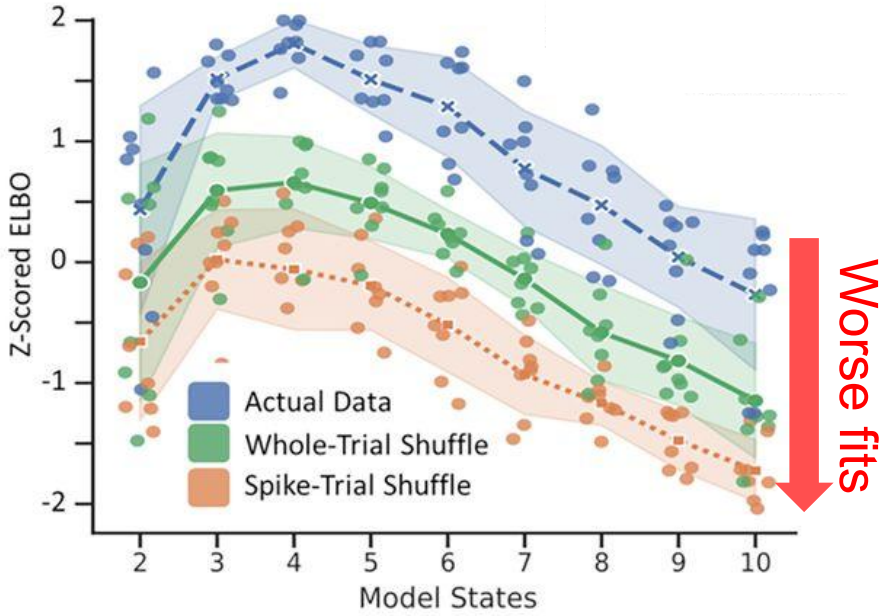




Mahmood et al. 2023

STATES IN BLA POPULATION ACTIVITY





Mahmood et al. 2023

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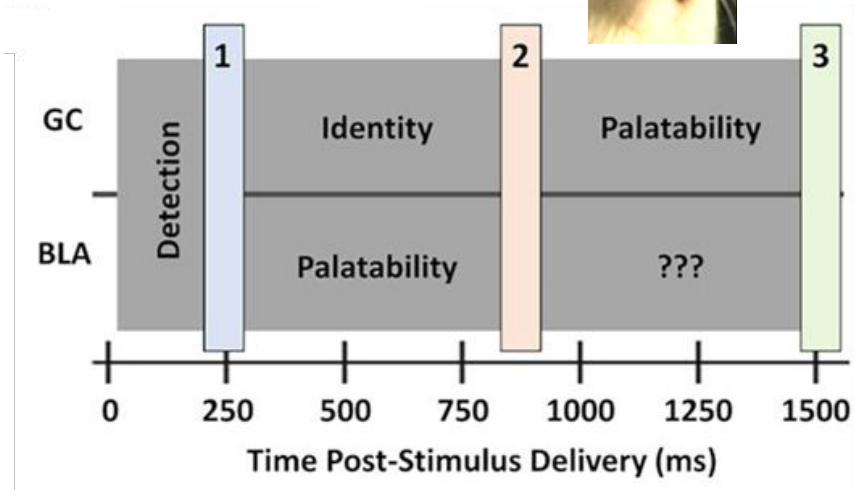
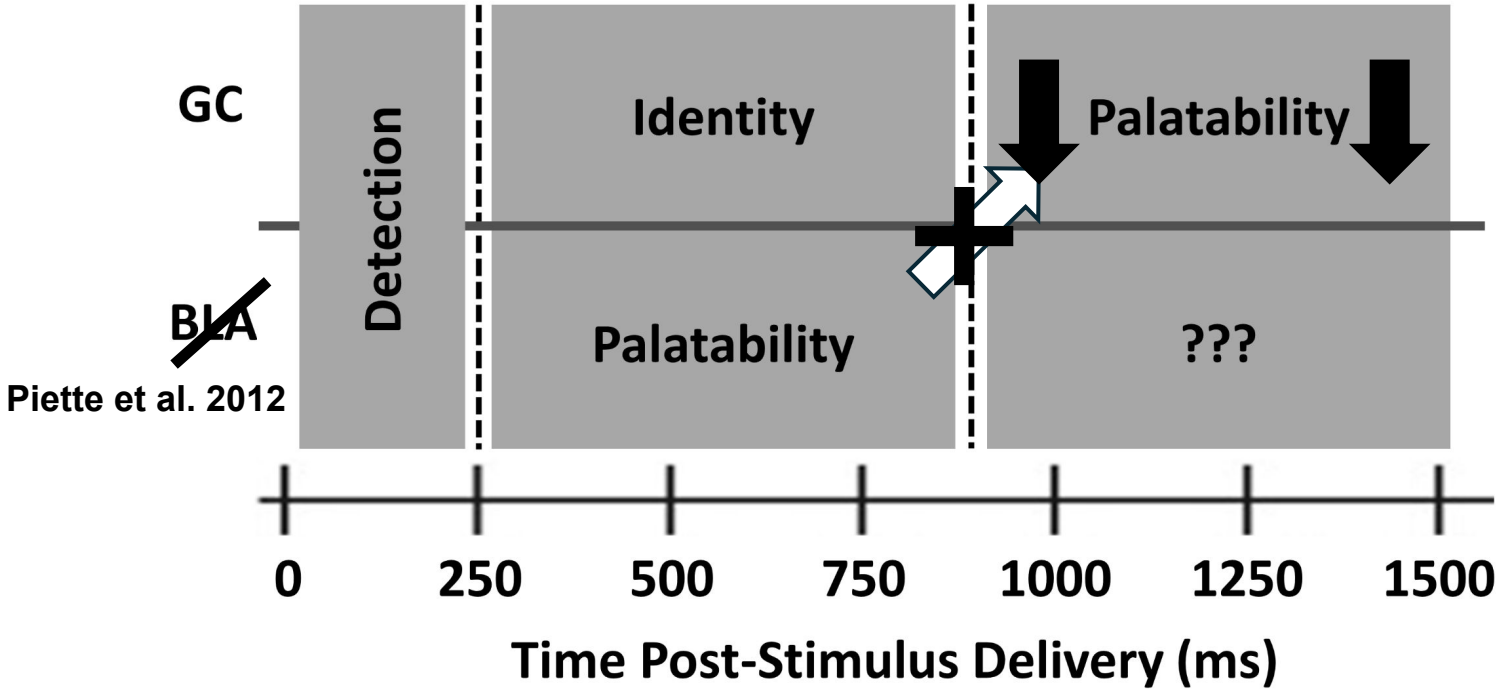
Here be gapes

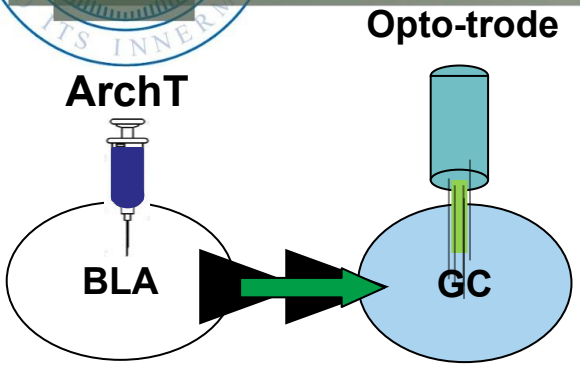


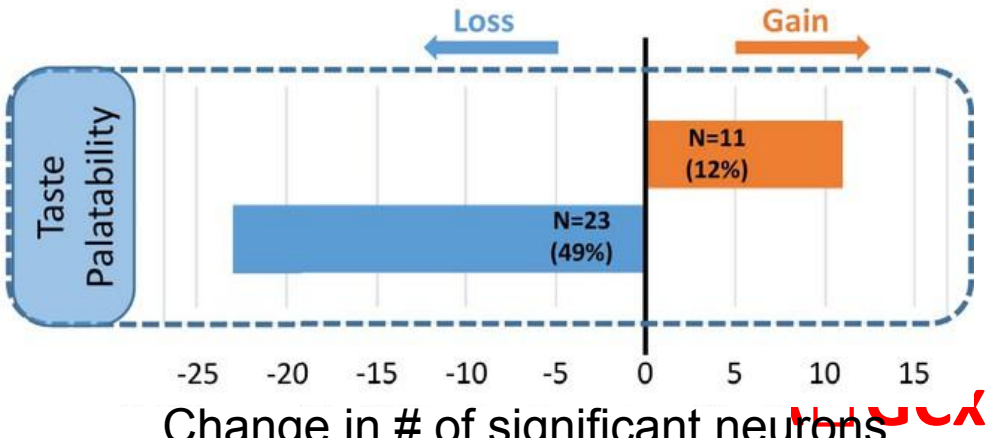
BLA AND GC COORDINATION IN AVERAGE ACTIVITY

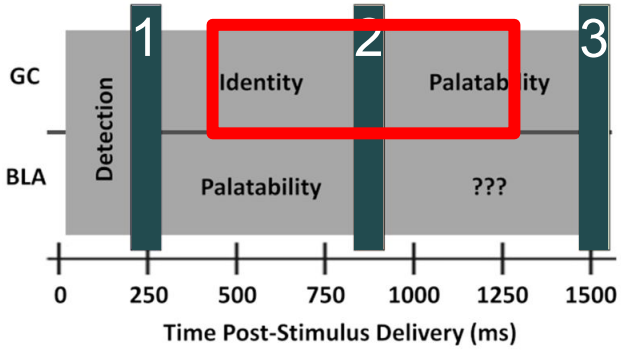


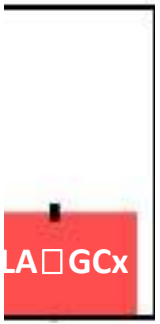
- Bechara, A., et al. "**Different Contributions of the Human Amygdala and Ventromedial Prefrontal Cortex to Decision-Making.**" 1999, https://doi.org/10.1523/JNEUROSCI.19-13-05473.1999.
- Schoenbaum, G., et al. "**Neural Encoding in Orbitofrontal Cortex and Basolateral Amygdala during Olfactory Discrimination Learning**." 1999, https://doi.org/10.1523/JNEUROSCI.19-05-01876.1999.

BLA is necessary for sharp transitions in GC



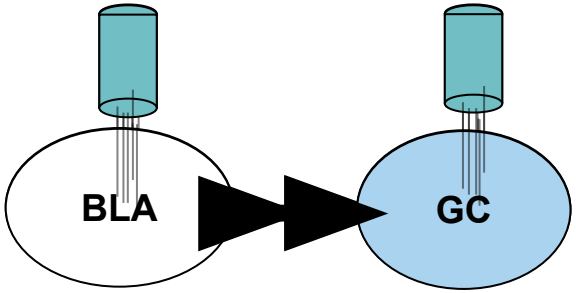


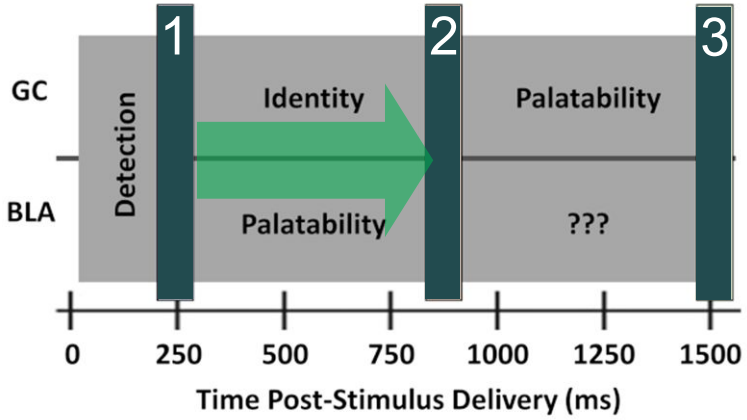


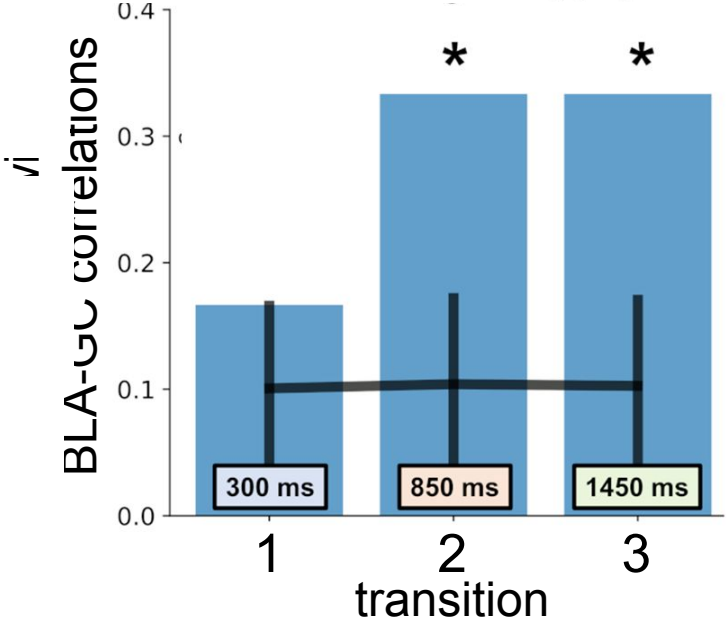


Lin et al, 2021

Amygdala and GC couple into a unit to process palatability







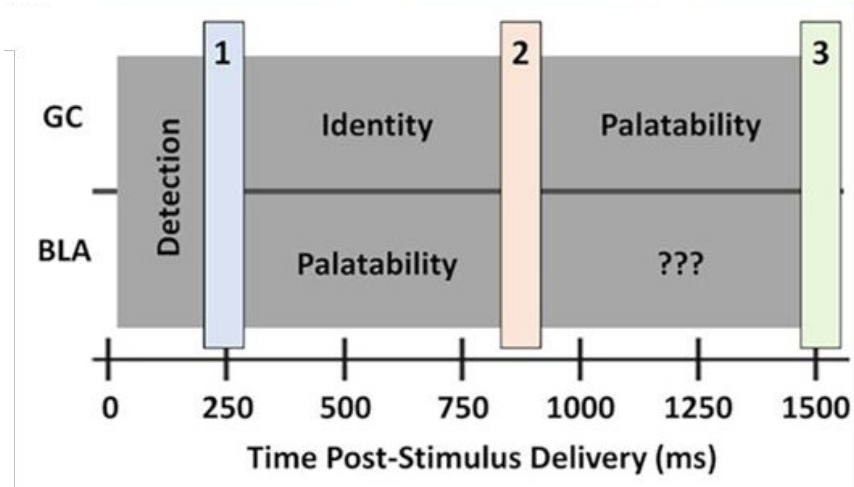
Mahmood et al, 2022

What's next for BLA and GC?

1. State-coordination is symmetric...and not zero-lag
2. Need to confirm lock-step coordination
3. And look at directional influences

PREDICTIONS #2

1. BLA-GC transition #2 will be ~~coordinated~~ synchronous
2. BLA will be driving GC to transition into palatability state (driving transition #2), after which GC emits behavioral command
3. Neurons involved in inter-region communication will have stronger taste encoding.



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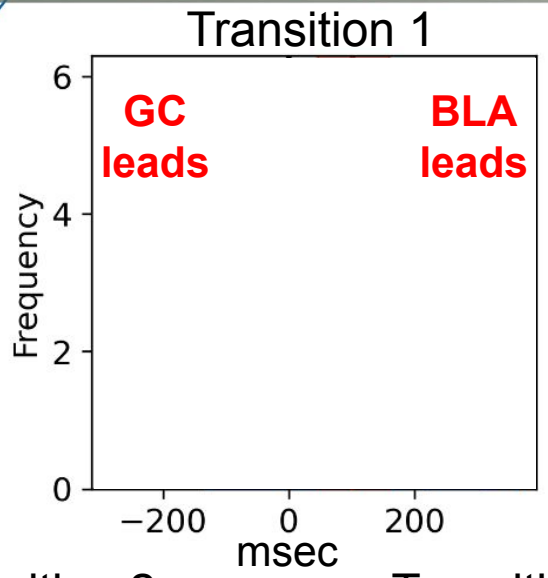

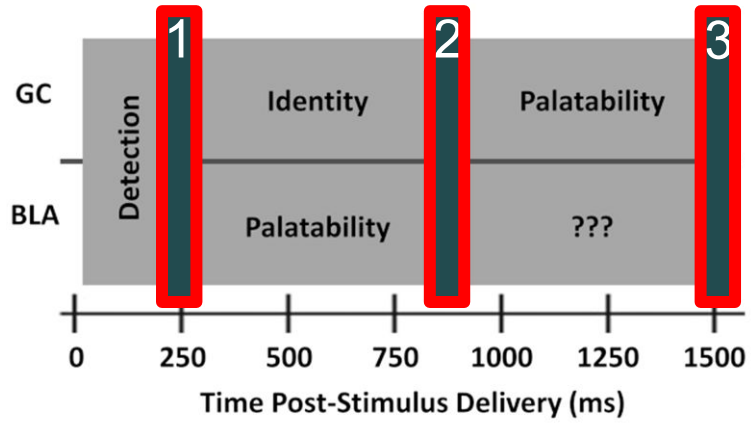

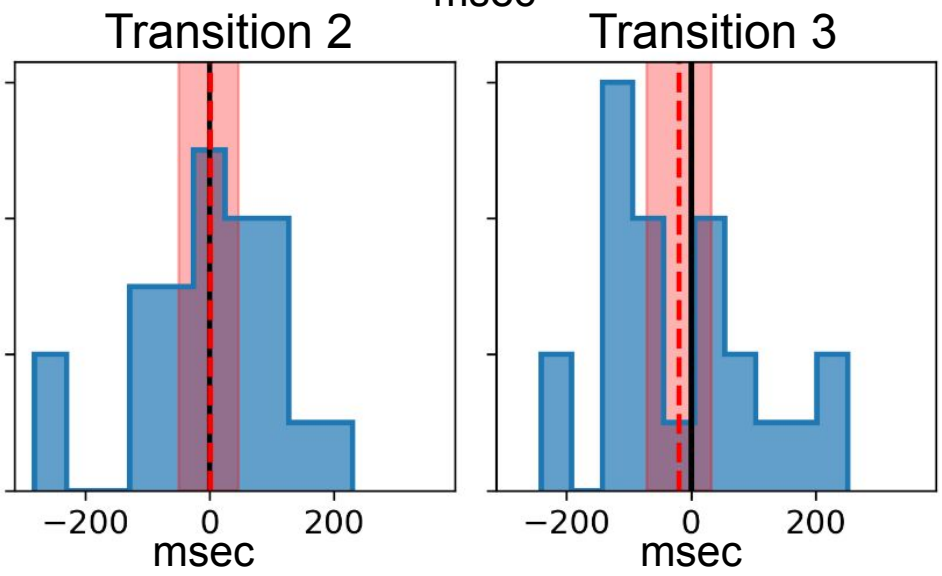

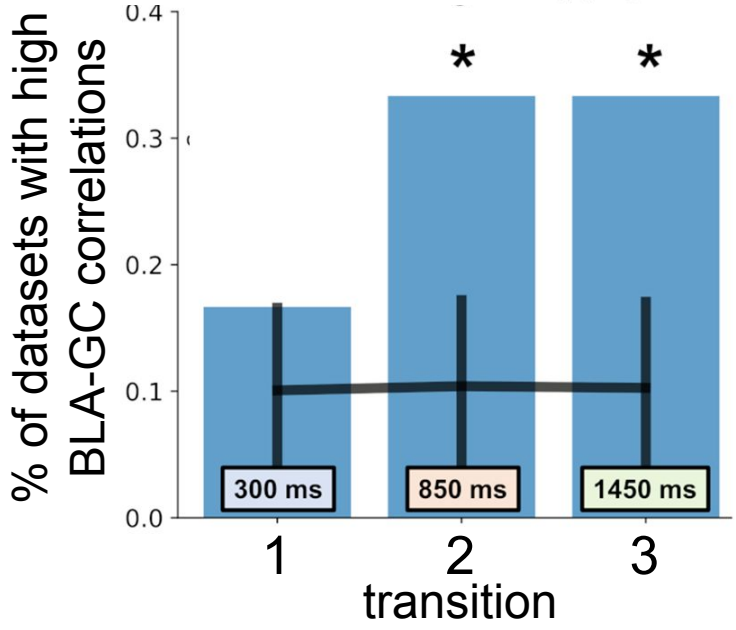

Mahmood, in prep

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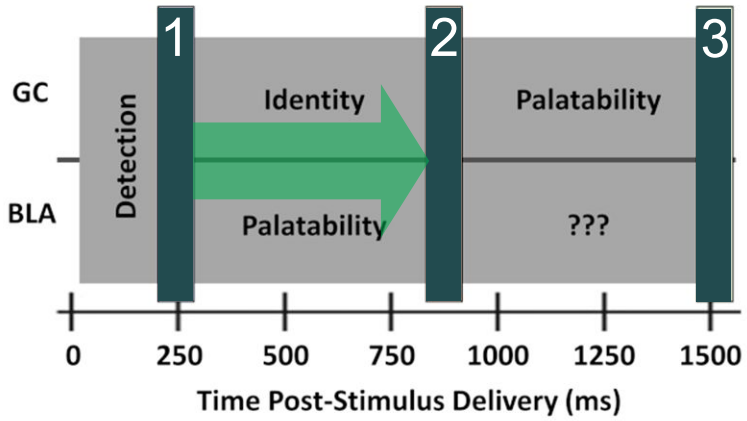
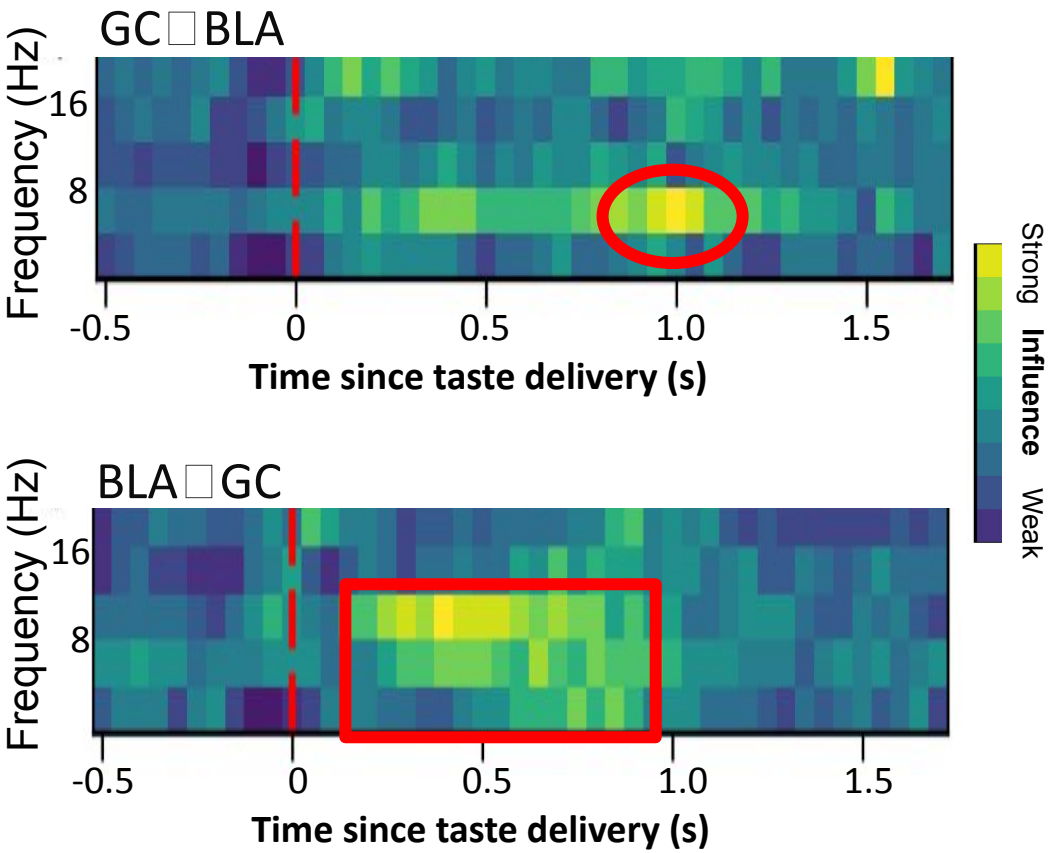
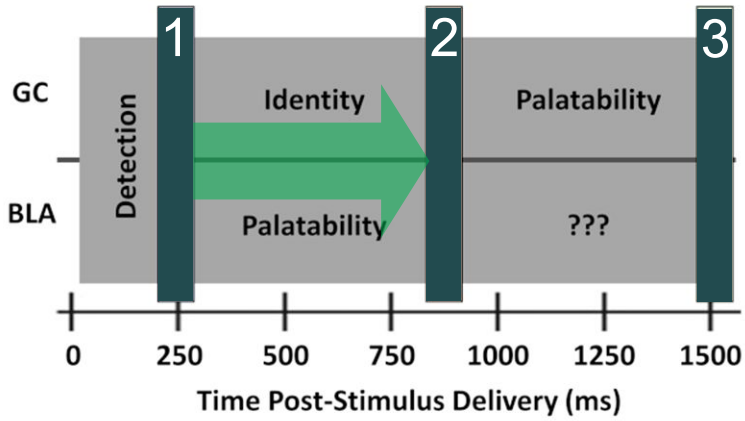


BLA influences GC on the way to amygdala-cortical coupling

Spectral Granger Causality





Mahmood, in prep

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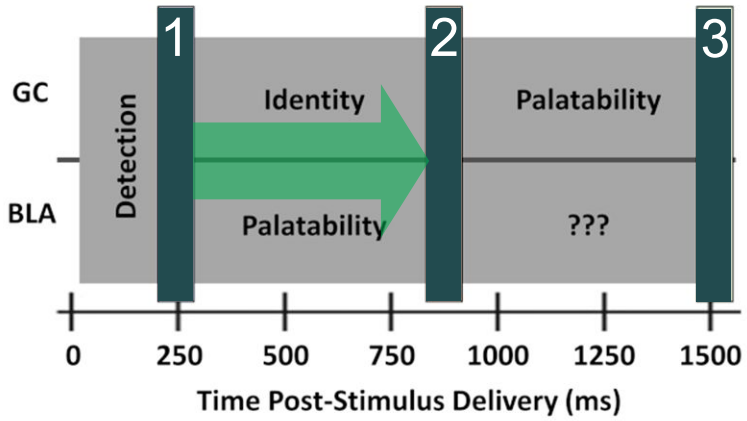
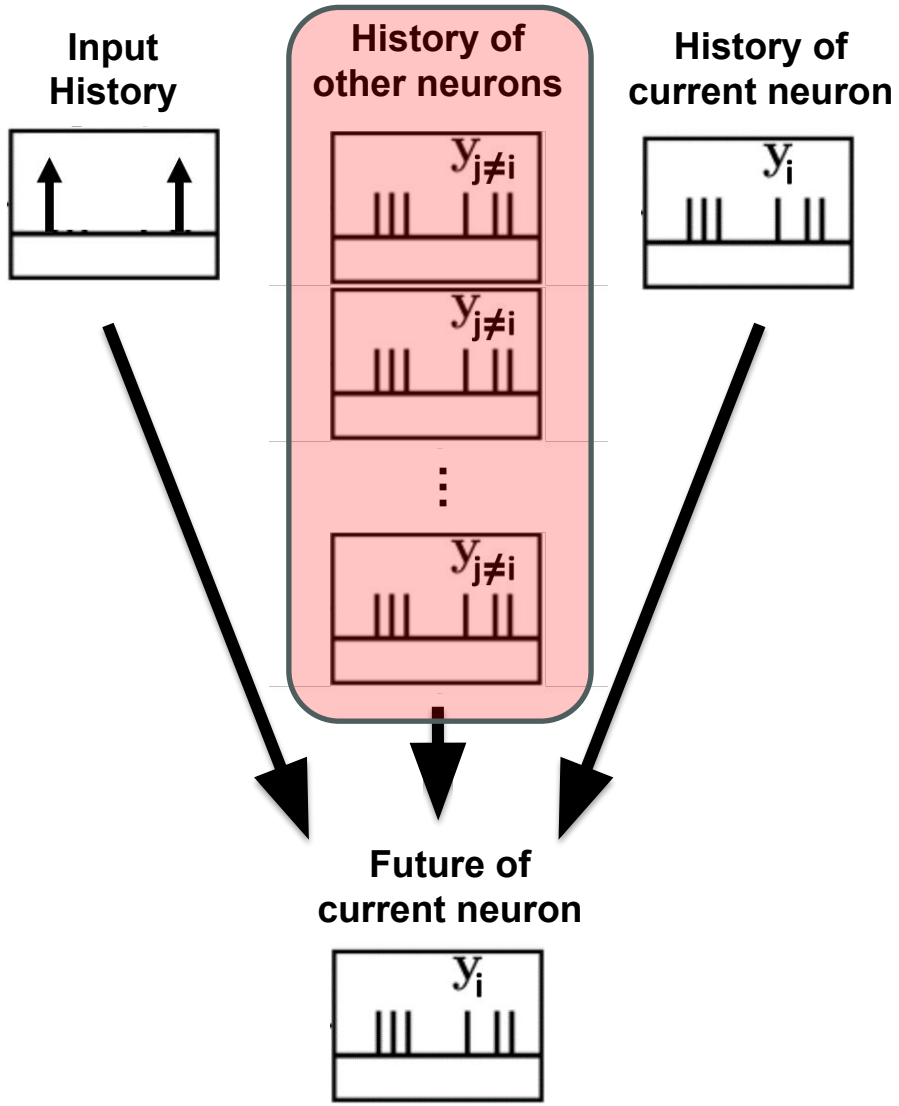


Embedding of neurons in the BLA-GC interactions is related to "tastiness"

Poisson Generalized Linear Modeling



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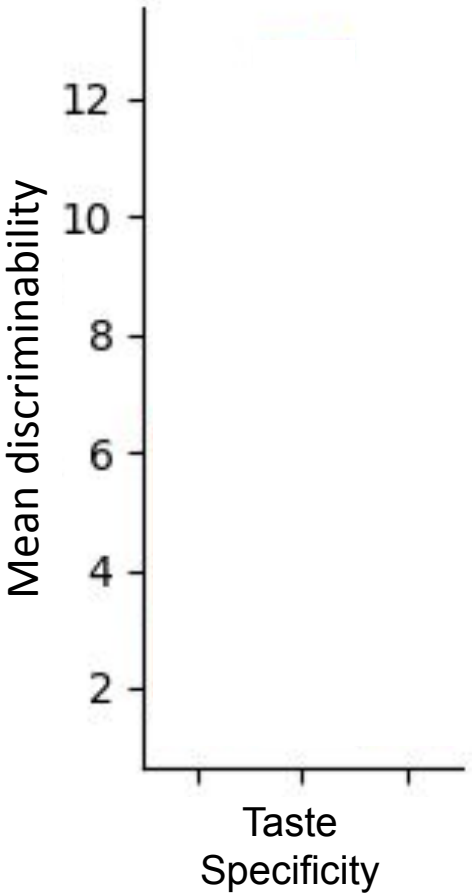
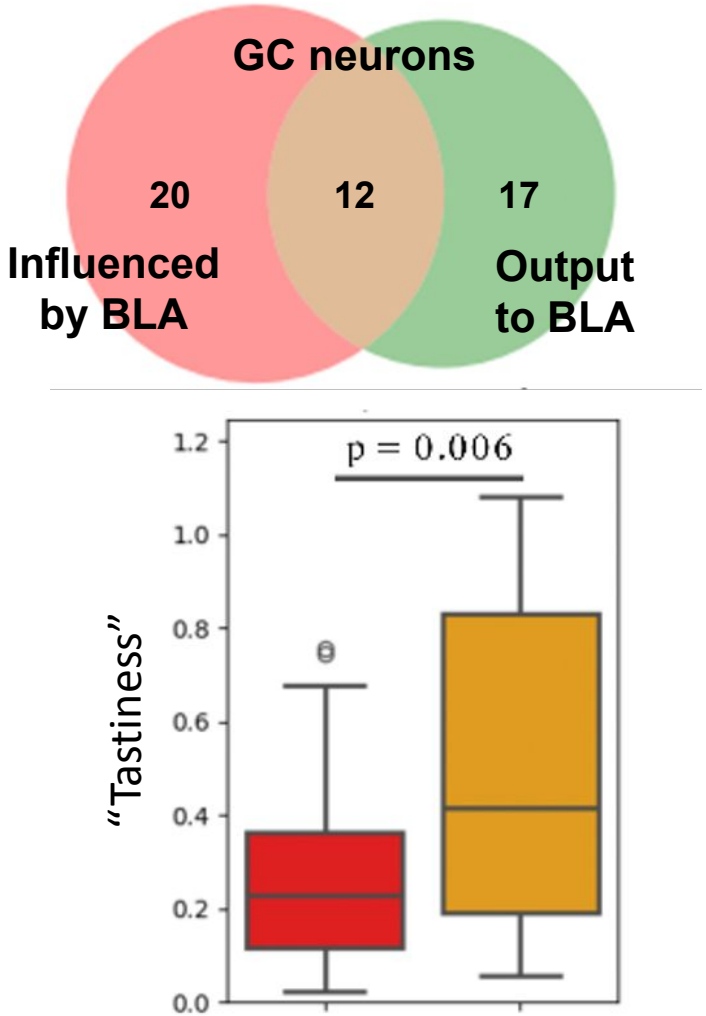
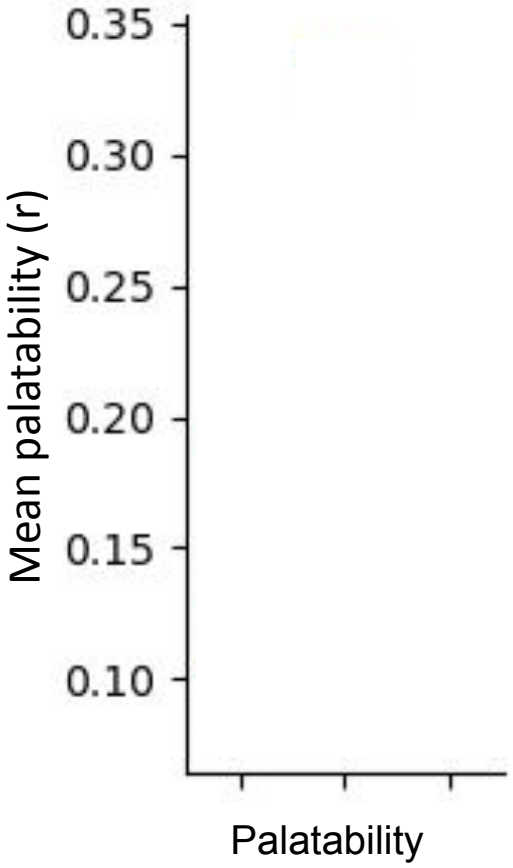






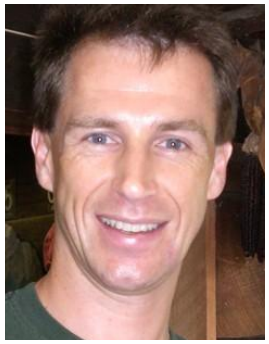
Mahmood, in prep

Obligatory summary slide

1. GC taste responses reflect taste ***processing*** across successive epochs.
2. Ensemble analysis of single trials reveals coding to emerge suddenly across ensemble transition.
3. These transitions in turn drives behavior… *probably by modulating a brainstem CPG*.
4. The mechanism of construction of this transition involves coupling of GC and BLA into a functional unit.

Acknowledgements

Behavior
Learning &
Electrophysiology
of
Emosensation
CH
Lab



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Jian-You Lin
Veronica Flores
Narendra Mukherjee
Meredith Blankenship
Bradly Stone
Kathleen Maigler

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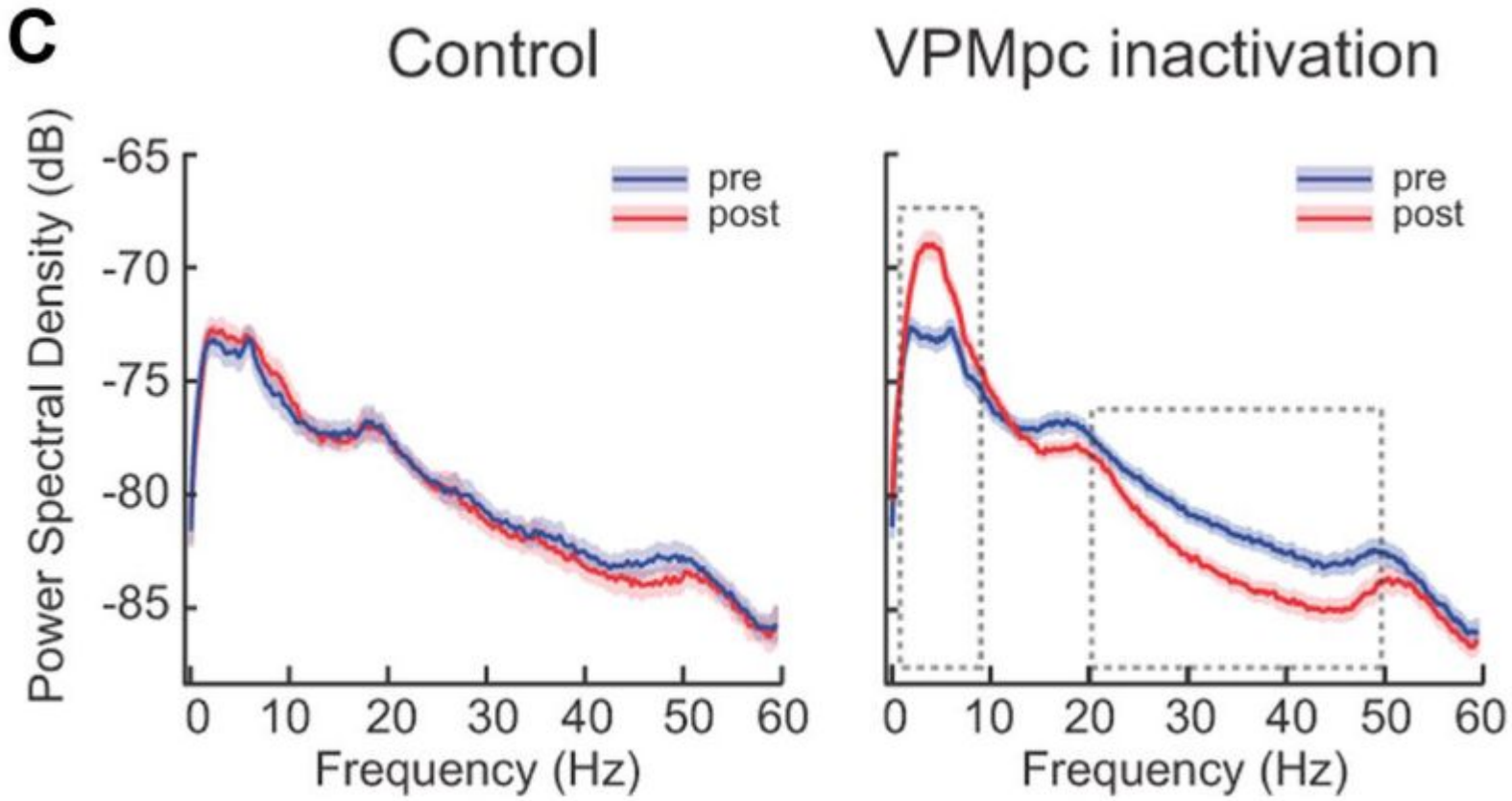
Linnea Herzog
Roshan Nanu
Natasha Baas-Thomas
Thomas Gray
Katie Kimbrell

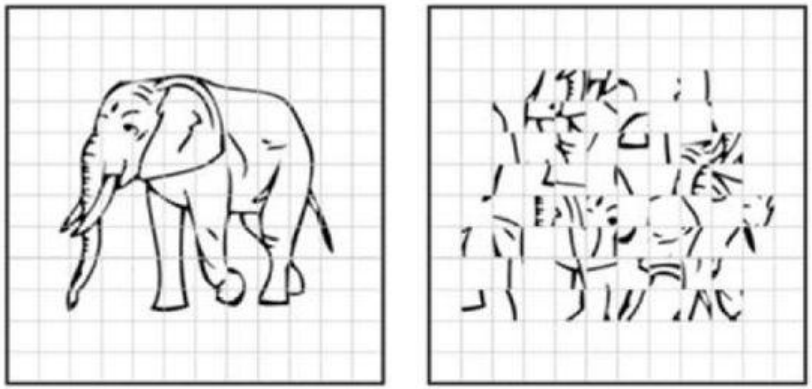
Funding
NIH (NIDCD)
NSF
Swartz Foundation

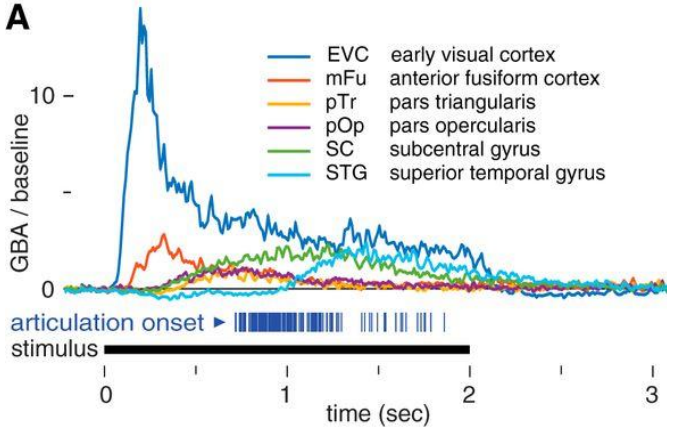
Thank you for your attention.

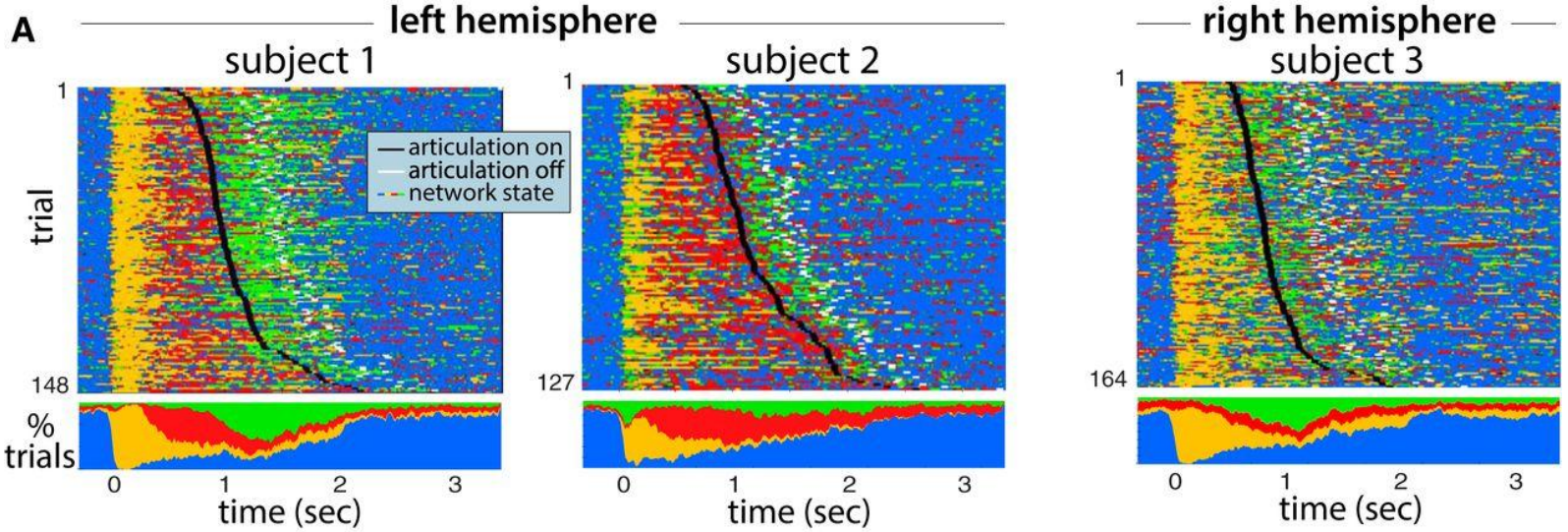
Samuelsen 2013



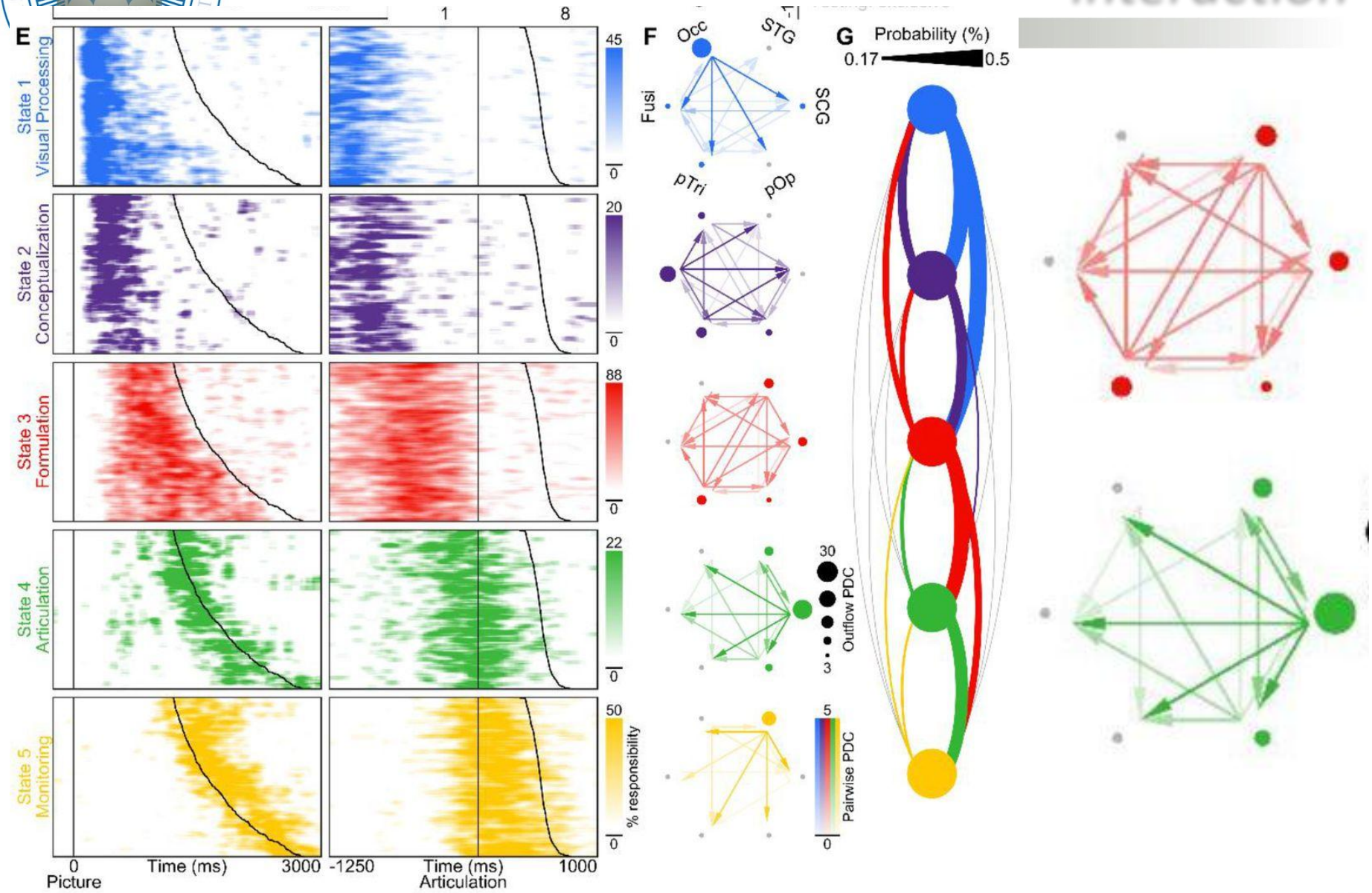
Saravani 2019, epoch



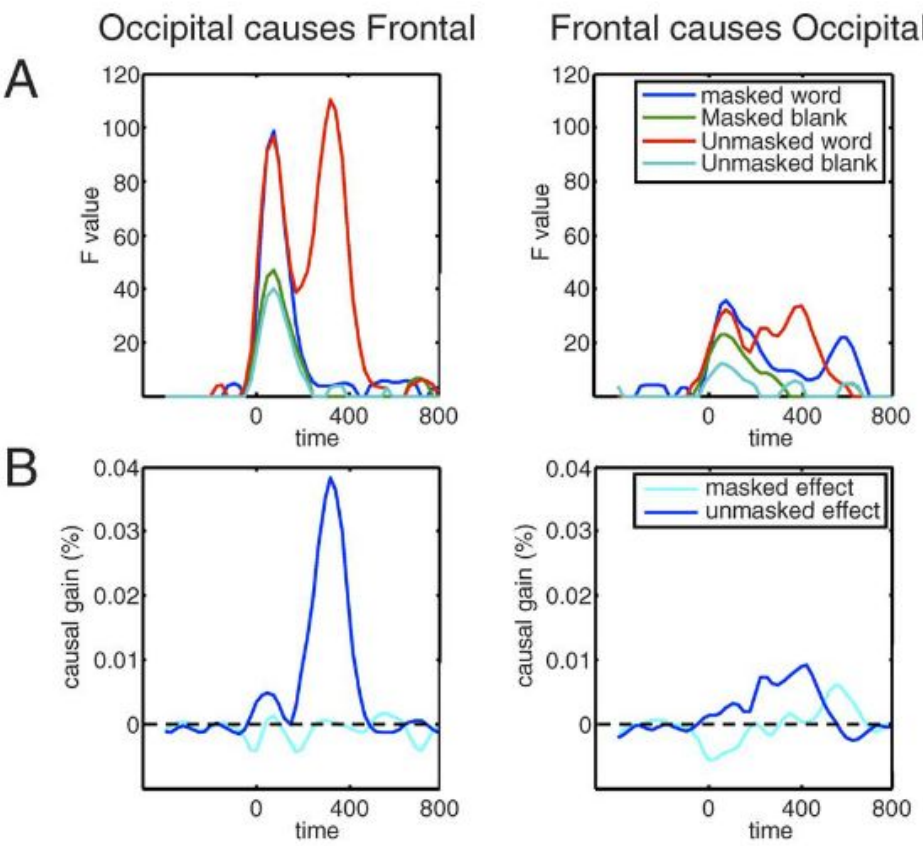


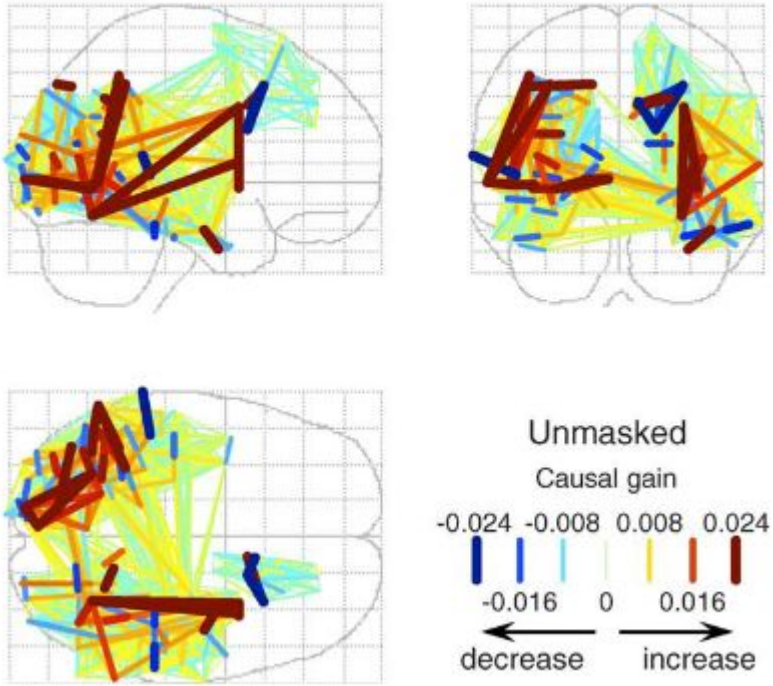


Forseth 2021 – distributed interaction

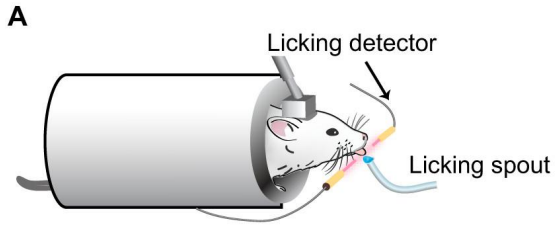


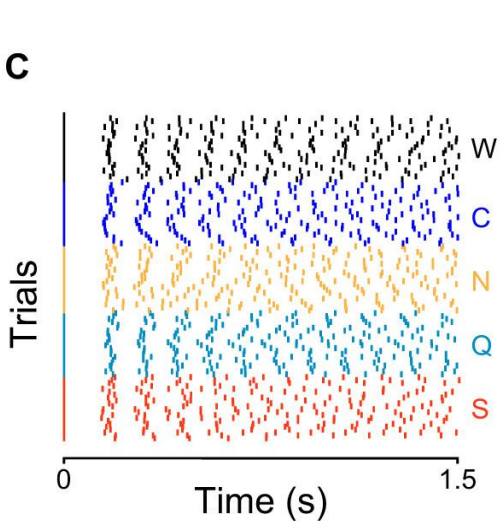
Global Workspace Theory (Gaillard 2009)

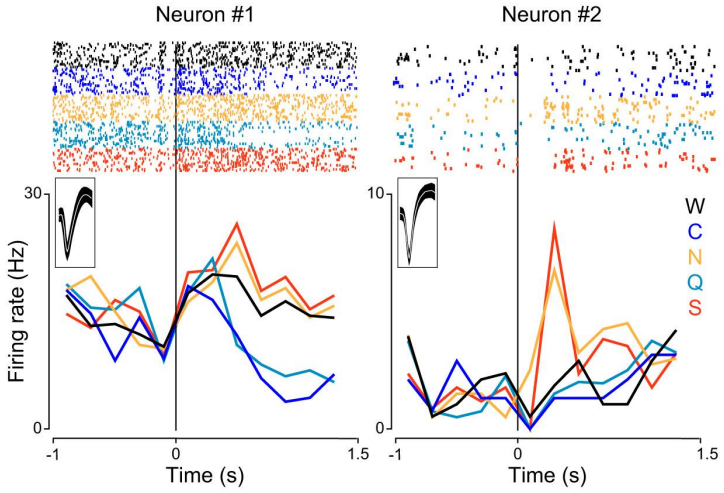


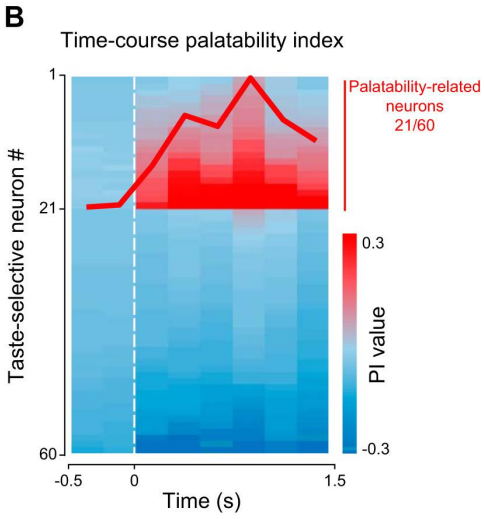


Bouaichi 2020, Licking-related GC Dynamics

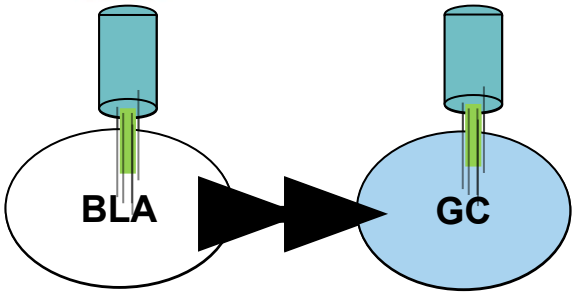


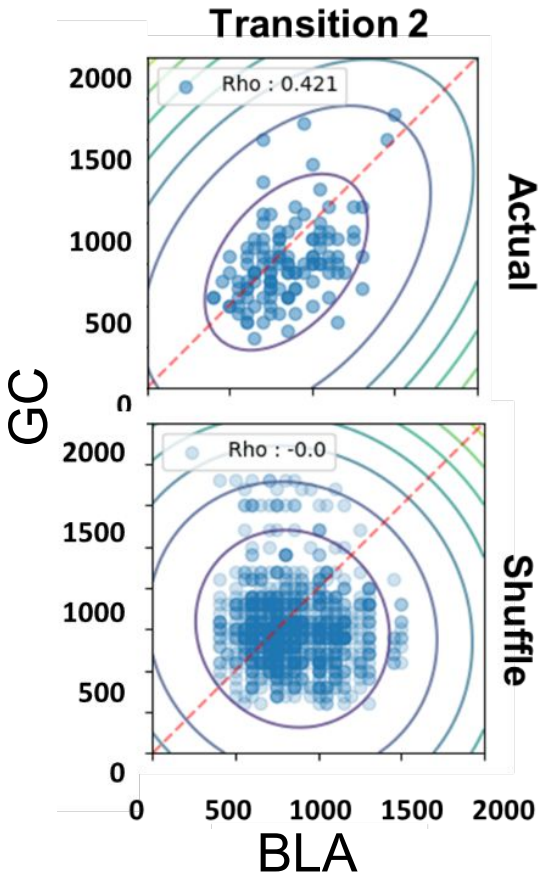






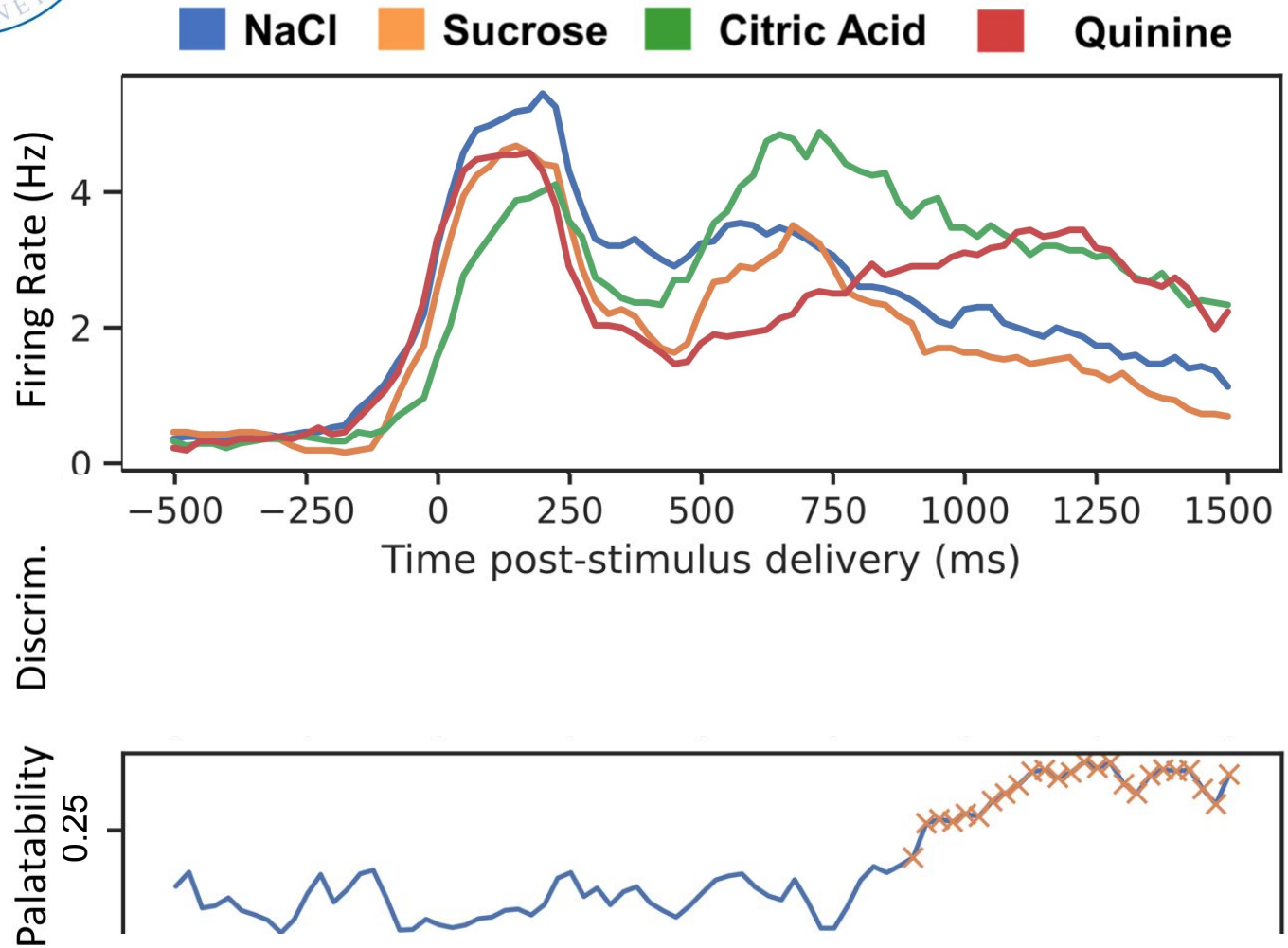
Amygdala and GC become a unit to process palatability





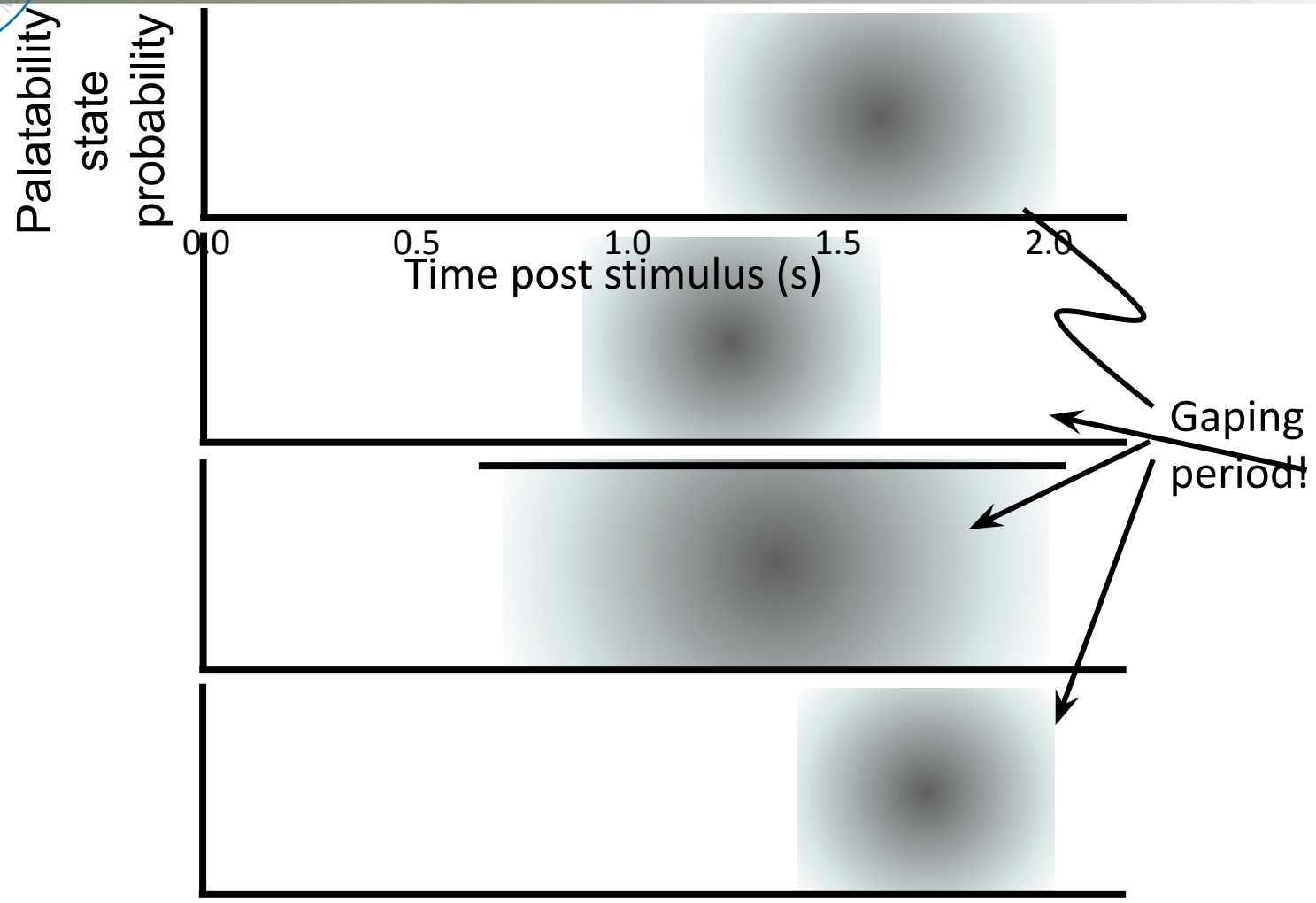
Mahmood et al, 2022

Gustatory cortical (GC) response dynamics culminate in decision-related firing



Mahmood, *et al.*, 2022

Ensemble state transitions reflect taste decision-making



Sadacca *et al*, 2016

Testing this characterization of GC taste processing

By manipulating palatability

Fontanini & Katz, 2006 (Reduction of arousal)

Grossman et al*., 2008, Moran & Katz, 2014* (taste aversion)

By challenging identity

Yoshida & Katz, 2010 (Taste discrimination [2AFC])

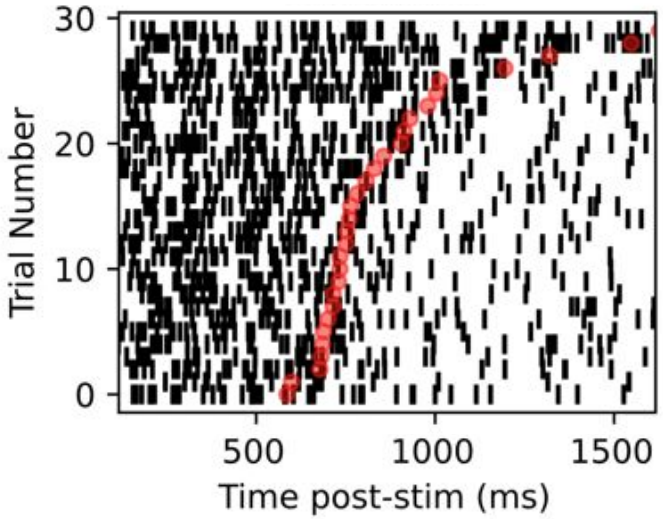
By directly changing gape latency

Li et al., *2016* (cuing aversive taste)

By perturbing GC activity

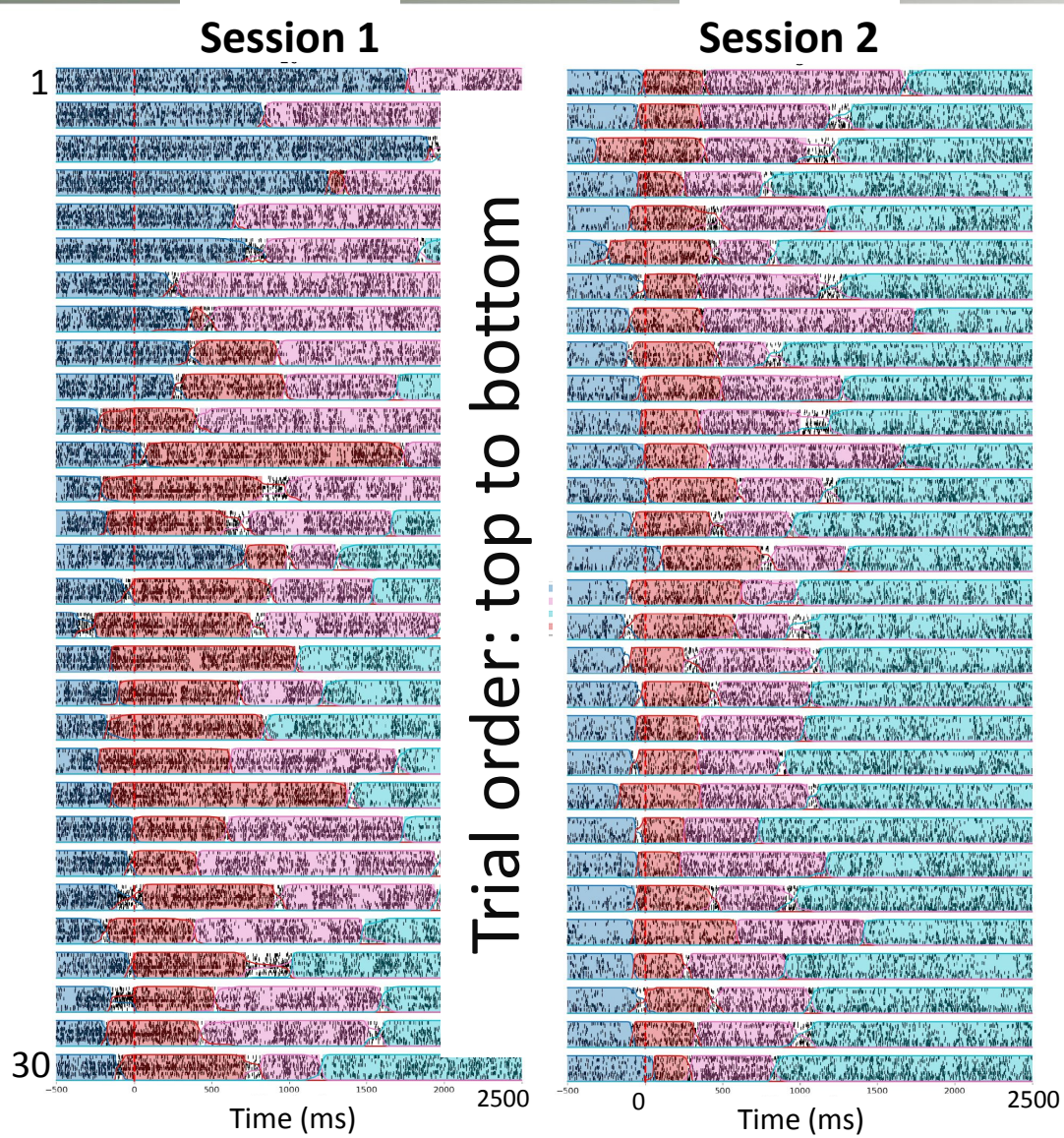
Mukherjee et al., *2019* (0.5 sec optogenetic silencing)

Single-neuron responses change suddenly when looked at in this way



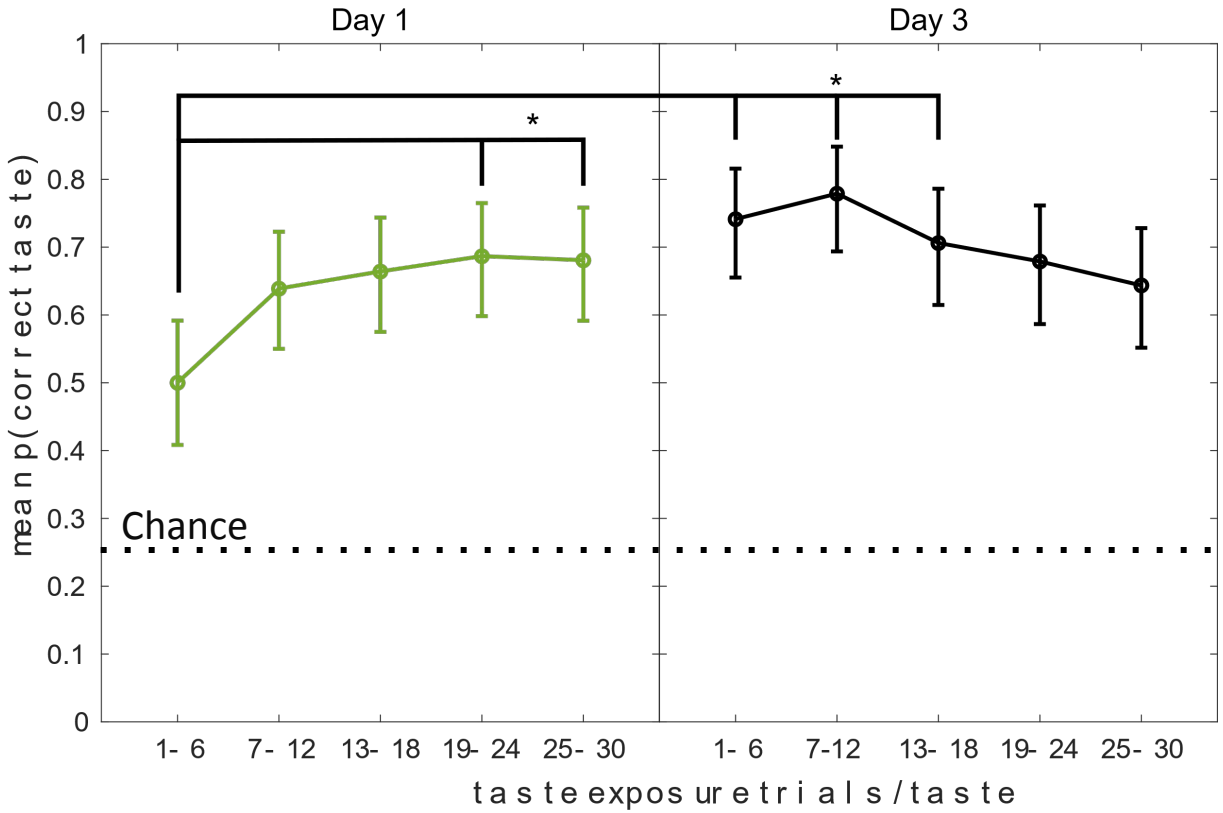
Sadacca, *et al.*, 2016
Mahmood, *et al.*, 2022

Scariest fact: taste response dynamics evolve over brief experience



Svedberg, *in prep*

This evolution impacts taste response discriminability



Svedberg, *in prep*