Neural circuits for decision-making in rats

Gidon Felsen
Mainen Lab
Cold Spring Harbor Laboratory

The big-picture question

- What are the neural bases of decision-making and goal-directed behavior?

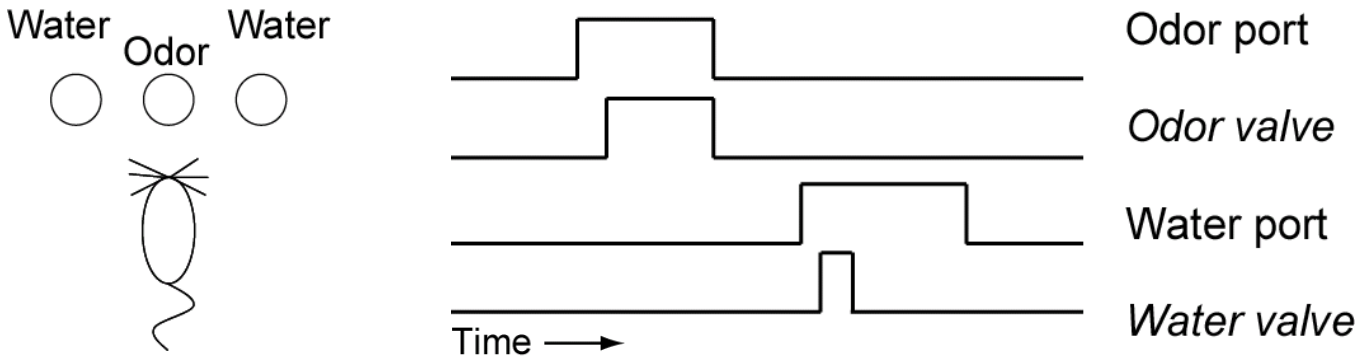
- How to investigate:
  - Develop a well-characterized decision-dependent behavior
  - Record and manipulate neural activity in multiple candidate areas during behavior
  - Determine how these areas work together to perform the necessary computations

Why study decision-making in rats?

- Rats are capable of performing behavioral tasks
- Neuronal mechanisms likely conserved across species
- Rats are cheaper and more convenient than primates
- Greater potential for manipulation of neural circuits in vivo (e.g., viral vector delivery)

Our decision-making paradigm

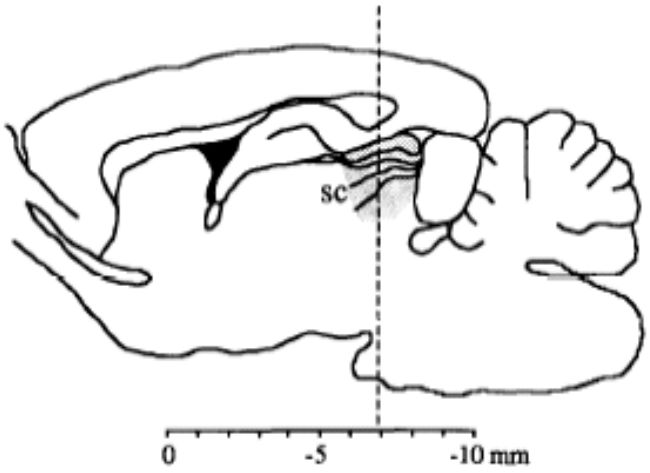
- 2-alternative choice odor discrimination (Uchida & Mainen, 2003)

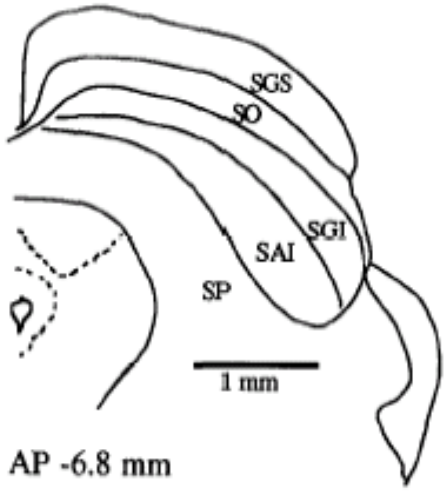


In the lab

In the wild

Region of interest: The superior colliculus



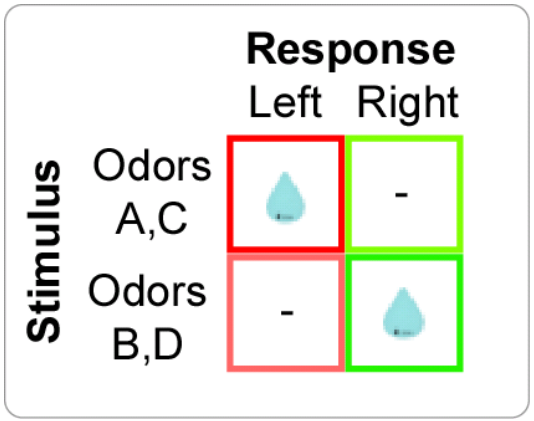


Dean *et al*., 1989

- Processes sensory input and motor output
  - Superficial layers: visual input
  - Intermediate: other sensory input; motor output
  - Deep: motor output
- Microstimulation produces stereotyped orienting movements (Sahibzada *et al*., 1986)
- Important component of decision circuit in primates (Horwitz & Newsome, 2001; Lo & Wang, 2006; Hikosaka *et al*., 2006)

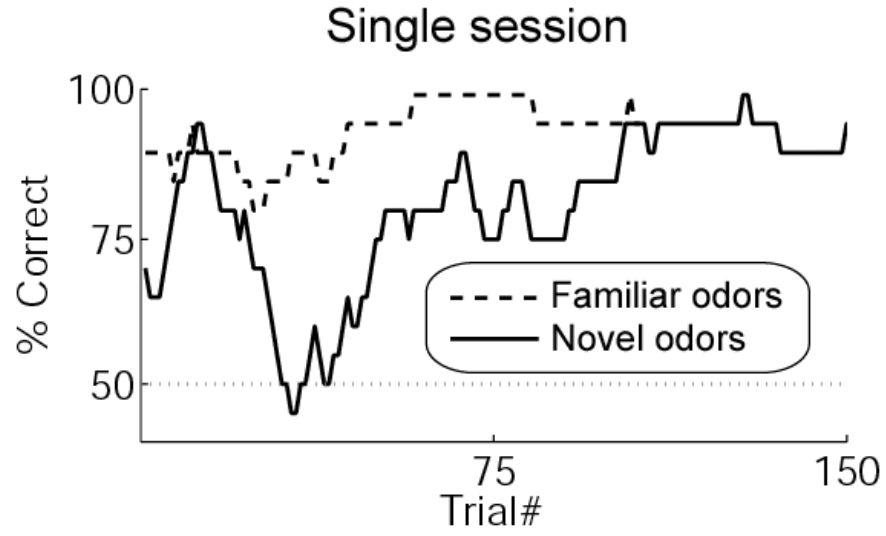
Methods: Behavioral task, recordings

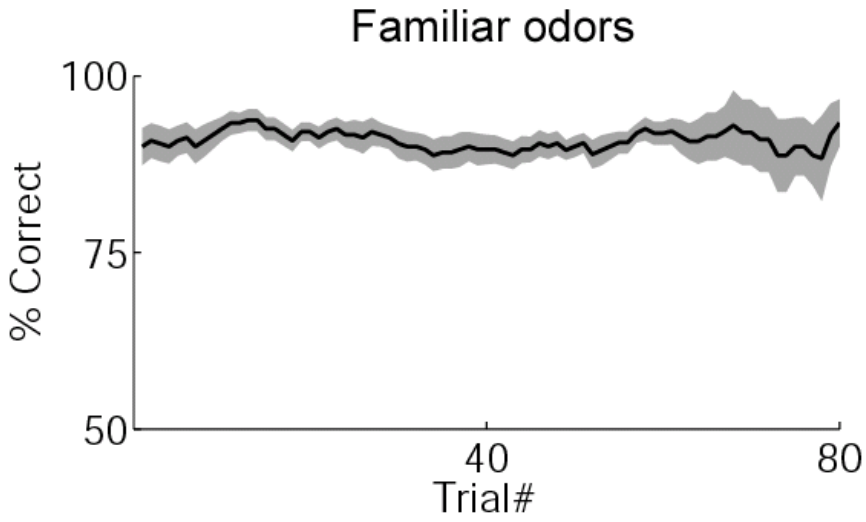
- 2 odor pairs per session: 1 familiar, 1 novel

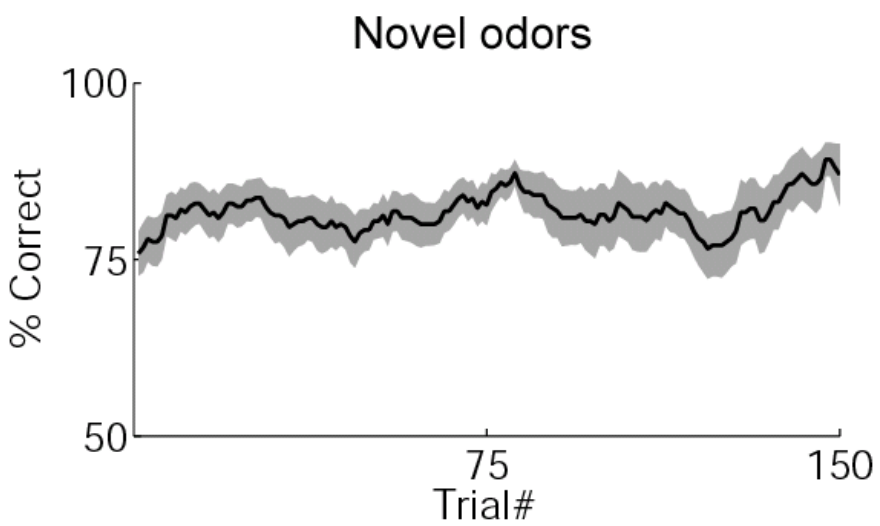


- 6-12 tetrodes implanted into left SC
  - AP -6.8; ML 1.7 (Paxinos & Watson, 2004)

Behavioral performance



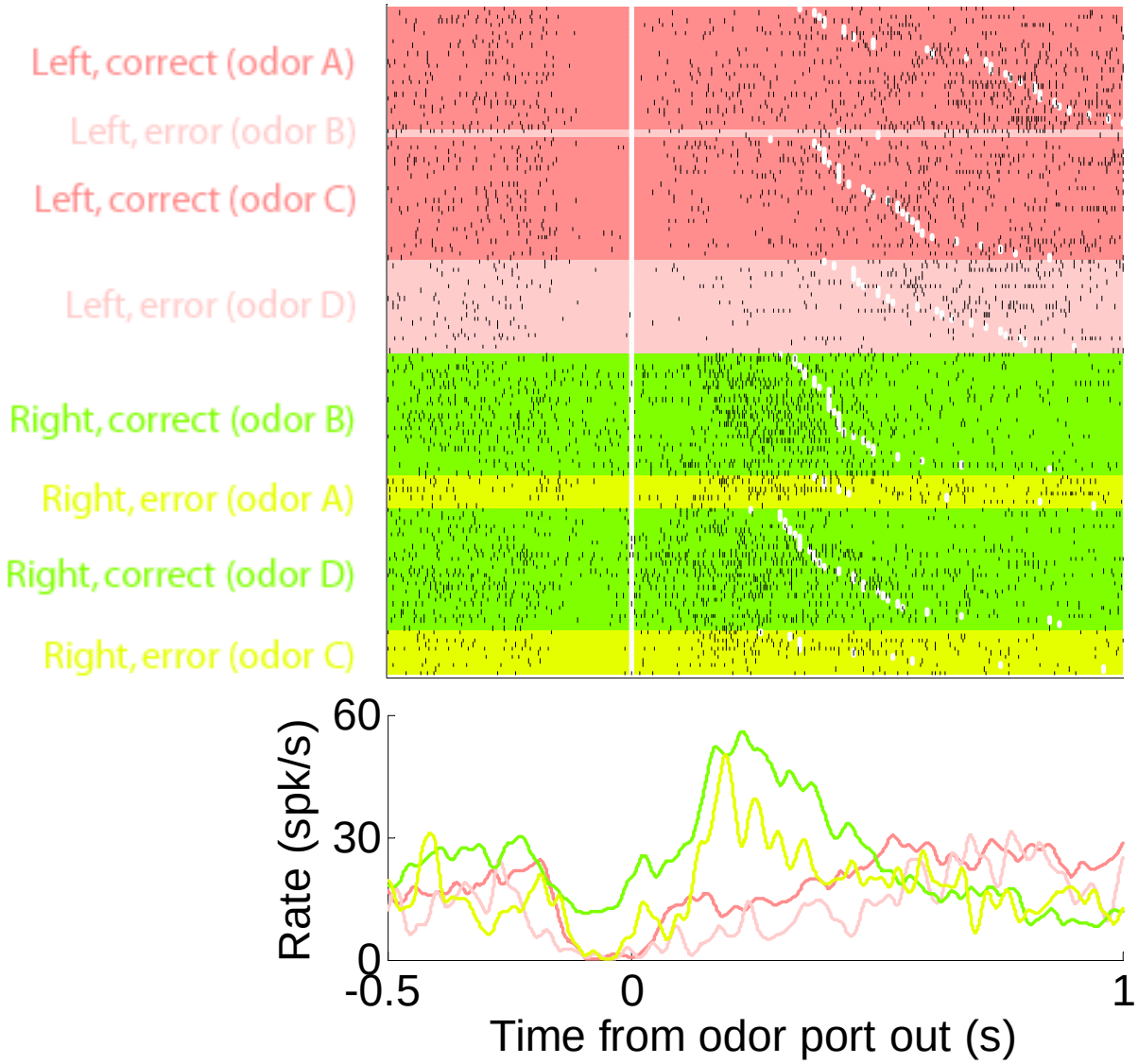


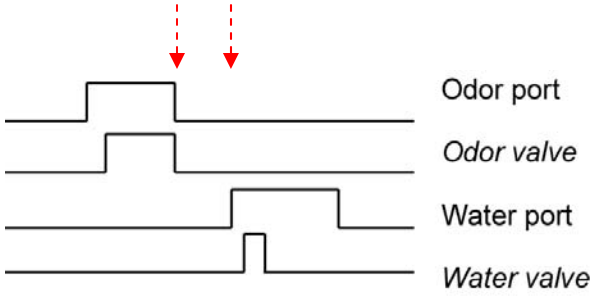


What neuronal activity might we expect to observe?

- Motor production: Activity selective for left vs. right during movement
- Motor planning: Direction selectivity preceding movement
- Decision-making: Activity representing the current stimulus and the upcoming motor plan

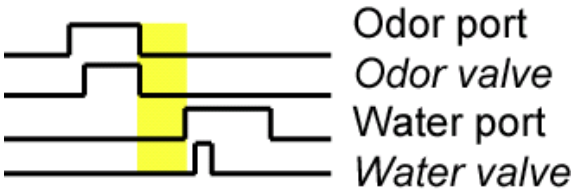
Direction selectivity during movement





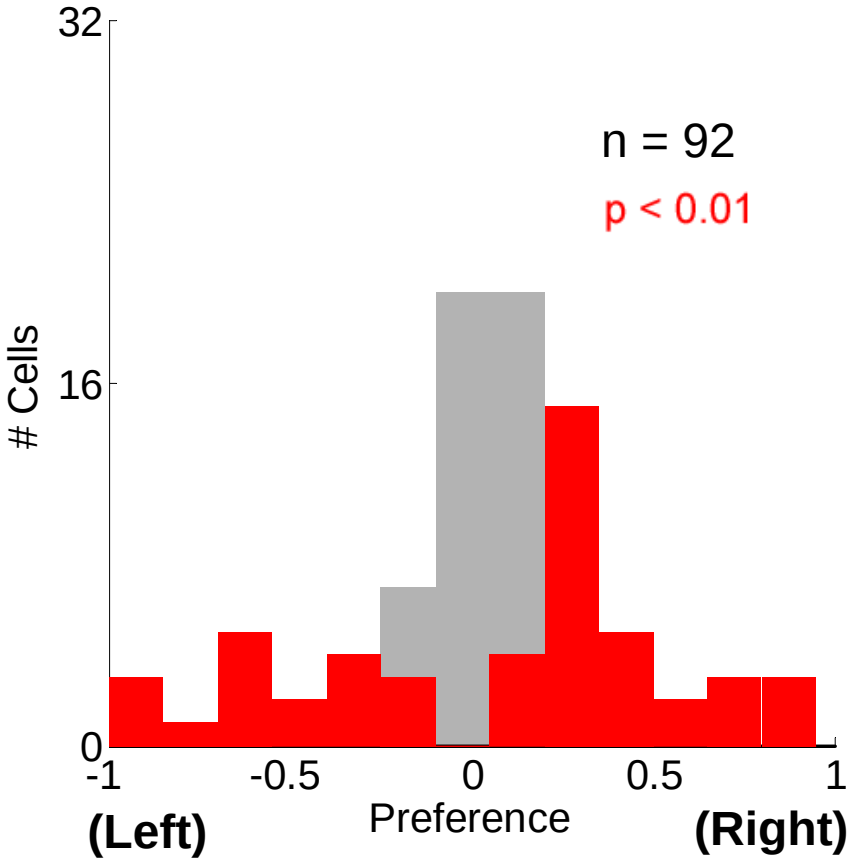
Movement preference across population

Epoch of interest

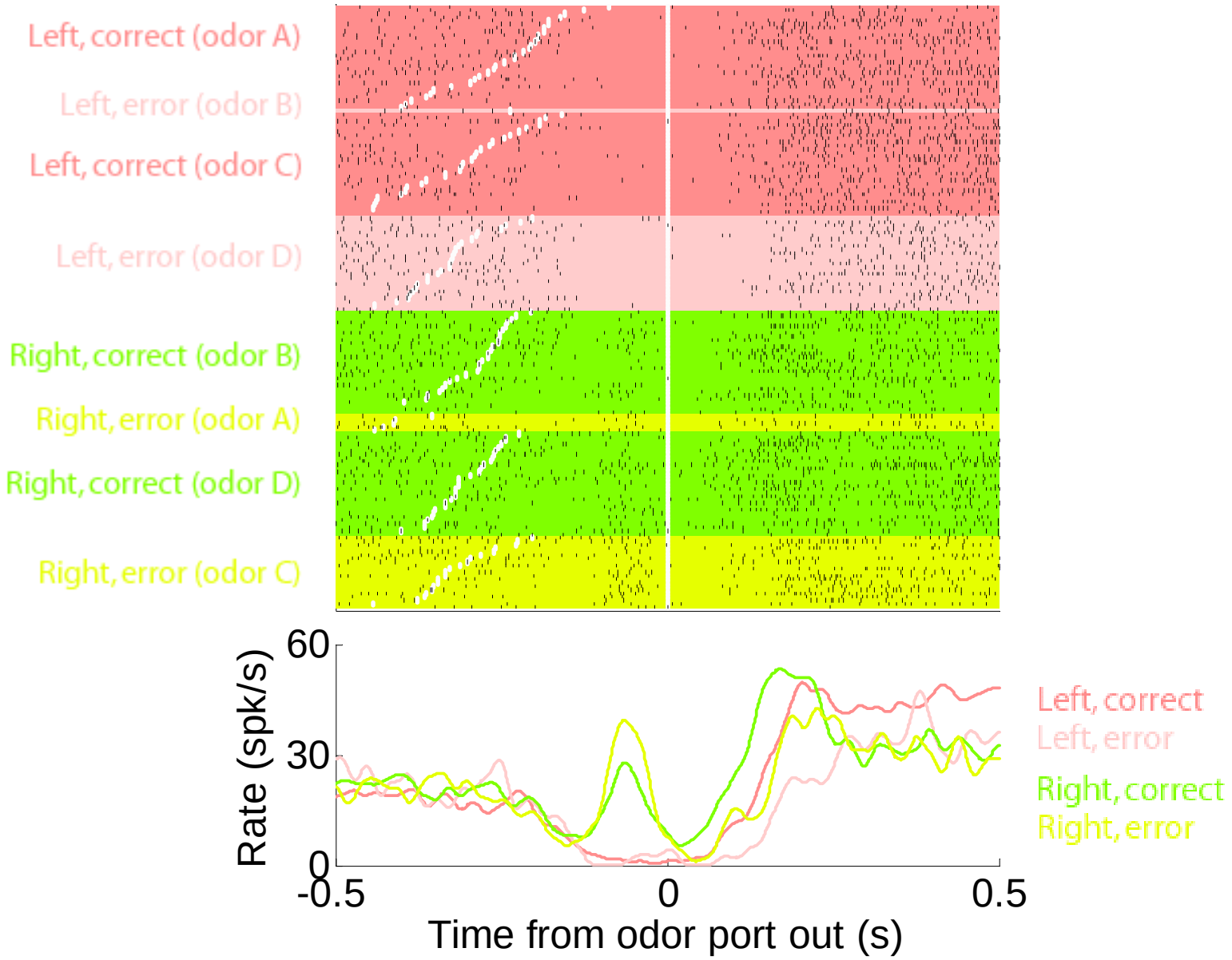


Calculate preference for left vs. right choice, independent of odor or correctness:

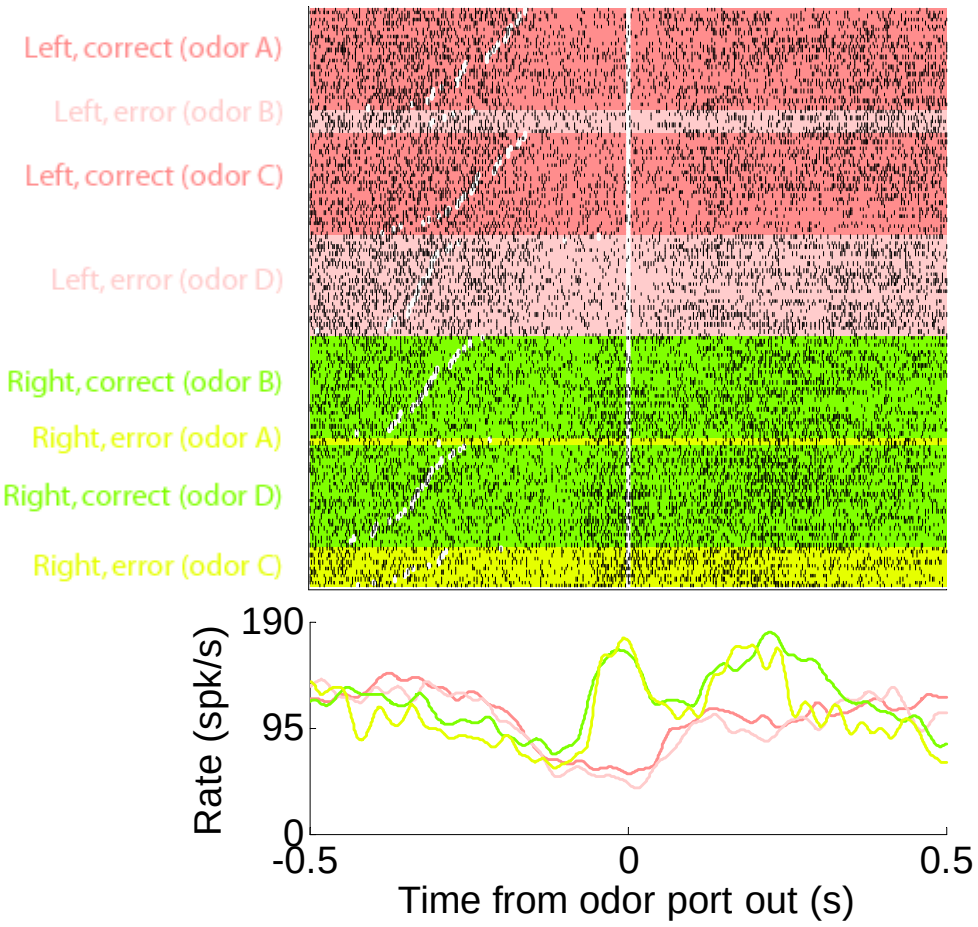
Preference = 2 * (ROC – 0.5)

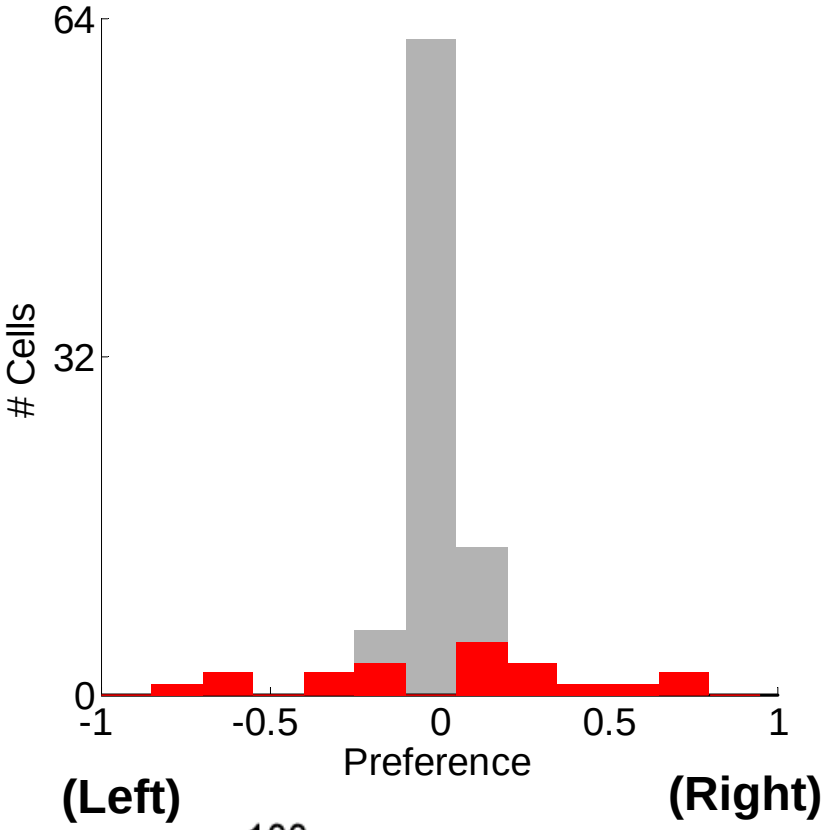


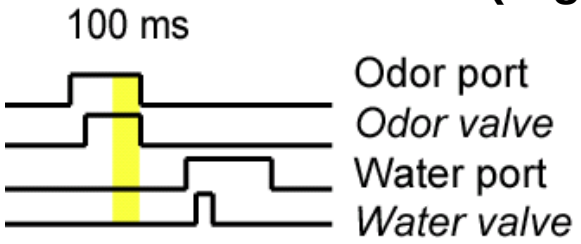
Choice-prediction in SC



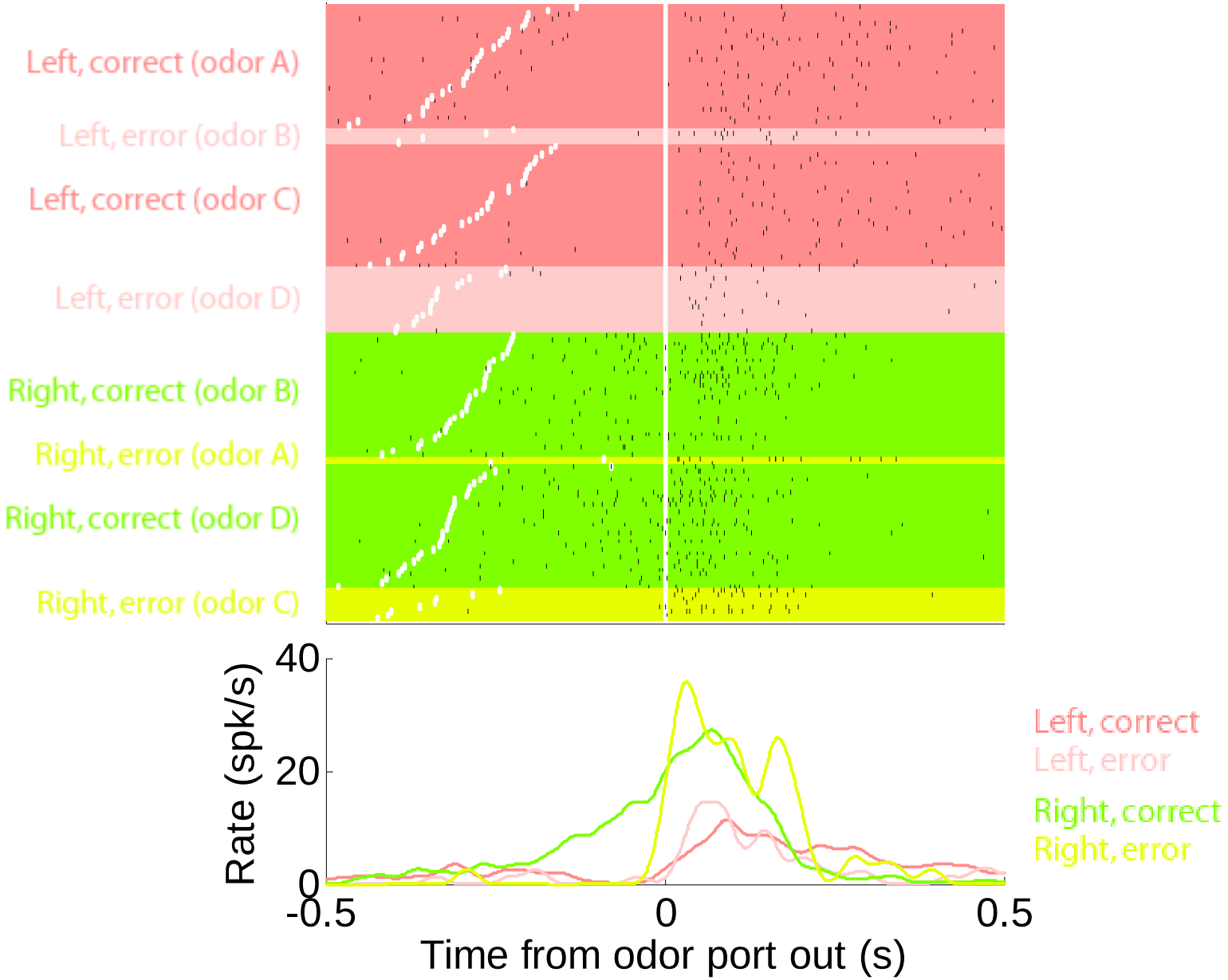
Choice-prediction across population







Conjunction of odor and choice



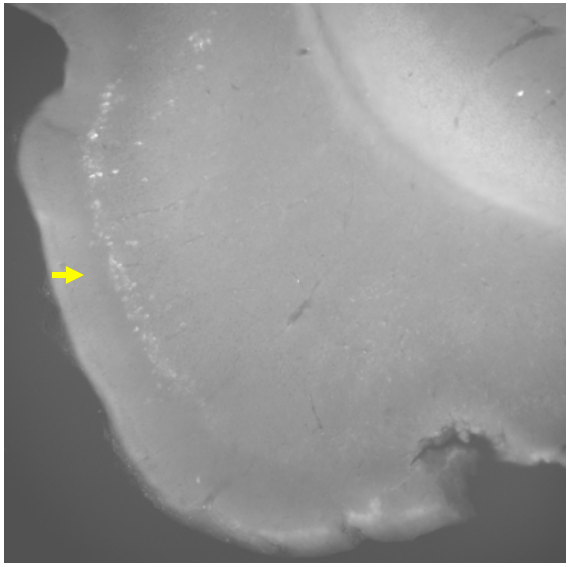
Where is SC in the decision-making circuit?

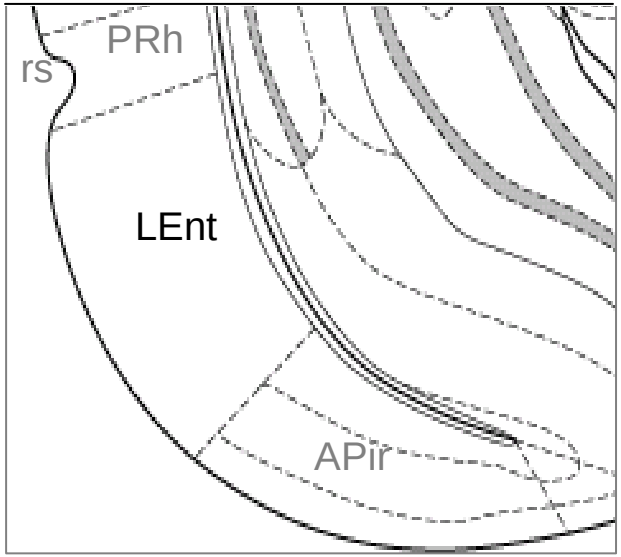
- Does the SC receive input from an area innervated by the olfactory bulb?
  - anterior olfactory nucleus
  - olfactory tubercle
  - piriform cortex
  - lateral entorhinal cortex
  - subregion of amygdala

- Retrograde tracing: Choleratoxin subunit B, conjugated to AlexaFluor 488 (Molecular Probes)
  - Labels cell bodies of neurons projecting to injection site

Preliminary results: Potential projection from lateral entorhinal cortex

Bregma -6 mm





Conclusions

- SC neurons are directionally-selective during movement.
- SC neurons predict movement direction, and link task-relevant sensory and motor information.
- The SC may be part of the circuit mediating the production of actions based on olfactory decisions.

Ongoing/Future directions

- Is SC activity layer-specific?
- Is the SC involved in decision-making, or motor planning?
  - What's going on upstream of SC?
- Is the observed activity necessary and/or sufficient for successful task performance?
- How is information integrated in order to make and act upon a decision?

Acknowledgments

Josh Sanders
Rachel Goldstein
Josh Cohen
Zach Mainen

Swartz Center for Computational Neuroscience

The End