

# Neural circuits for decision-making in rats

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# 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

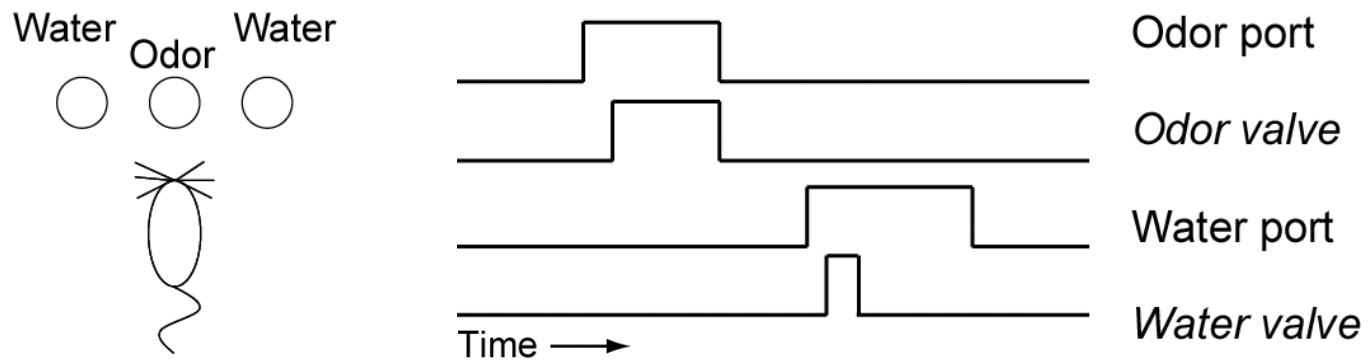
# Why study decision-making in rats?

- 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)



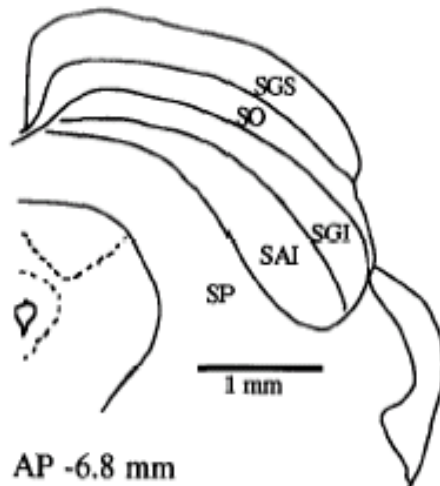
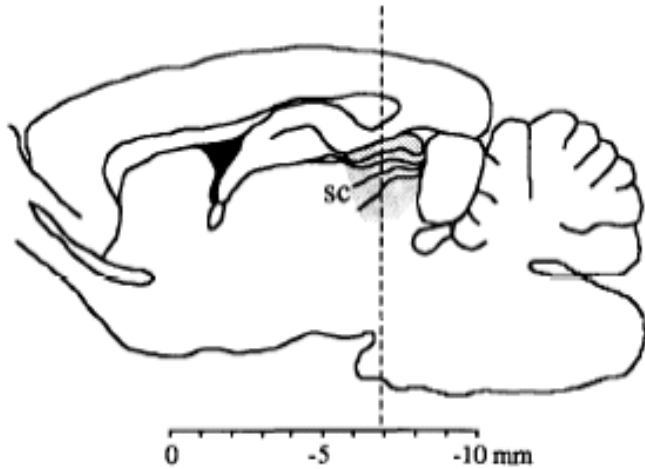
In the lab



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)

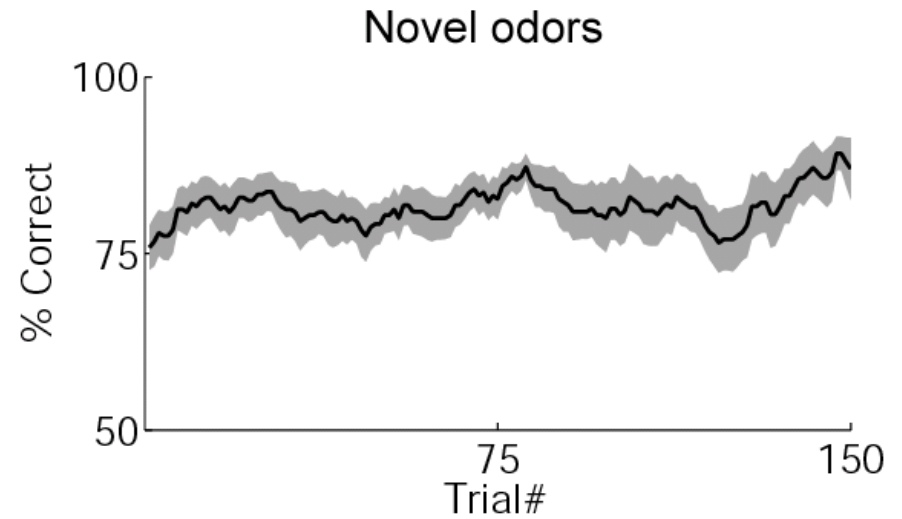
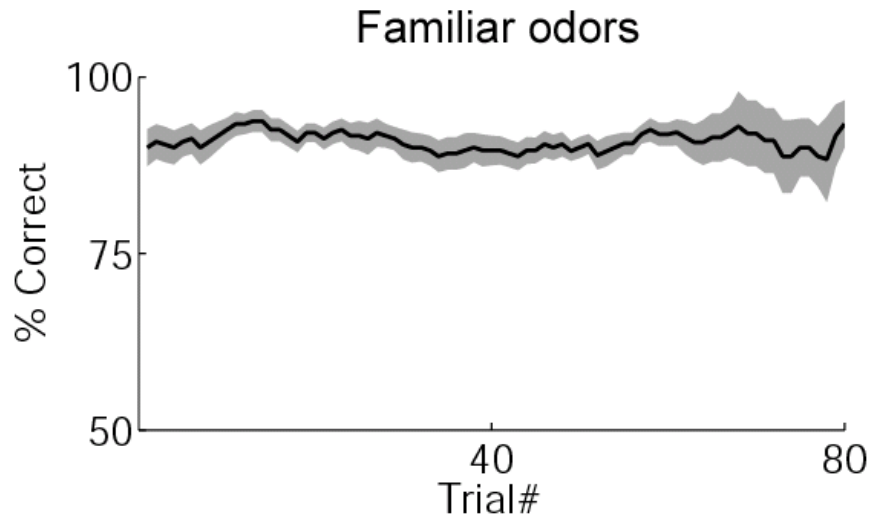
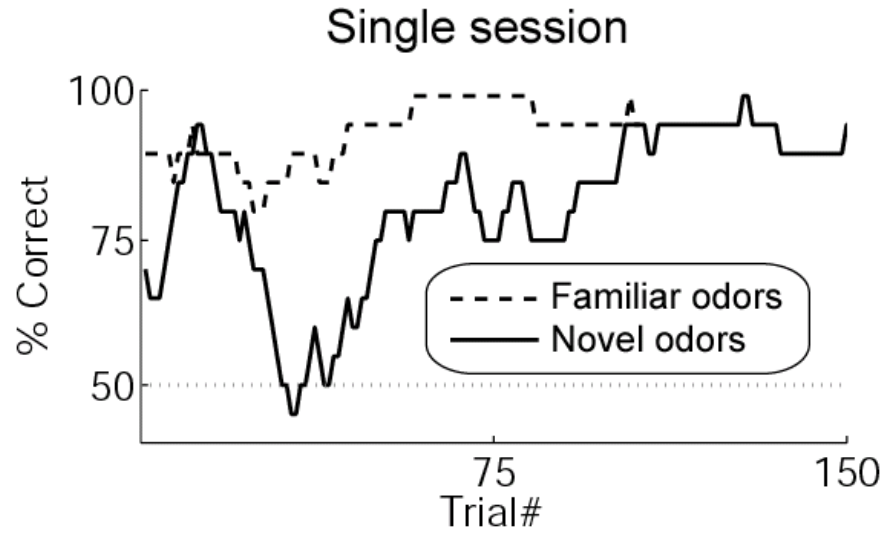
# Methods: Behavioral task, recordings

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

		Response	
		Left	Right
Stimulus	Odors A,C		-
	Odors B,D	-	

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

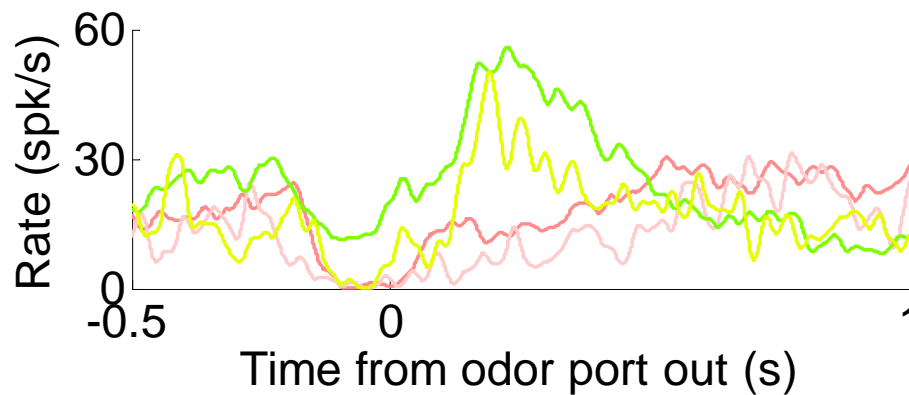
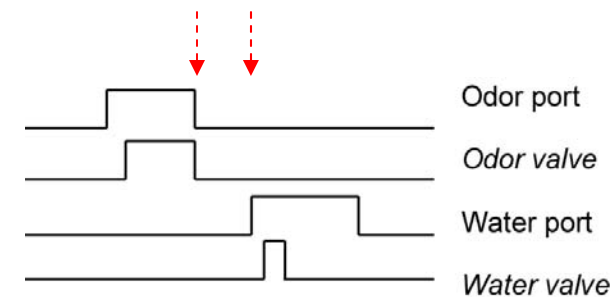
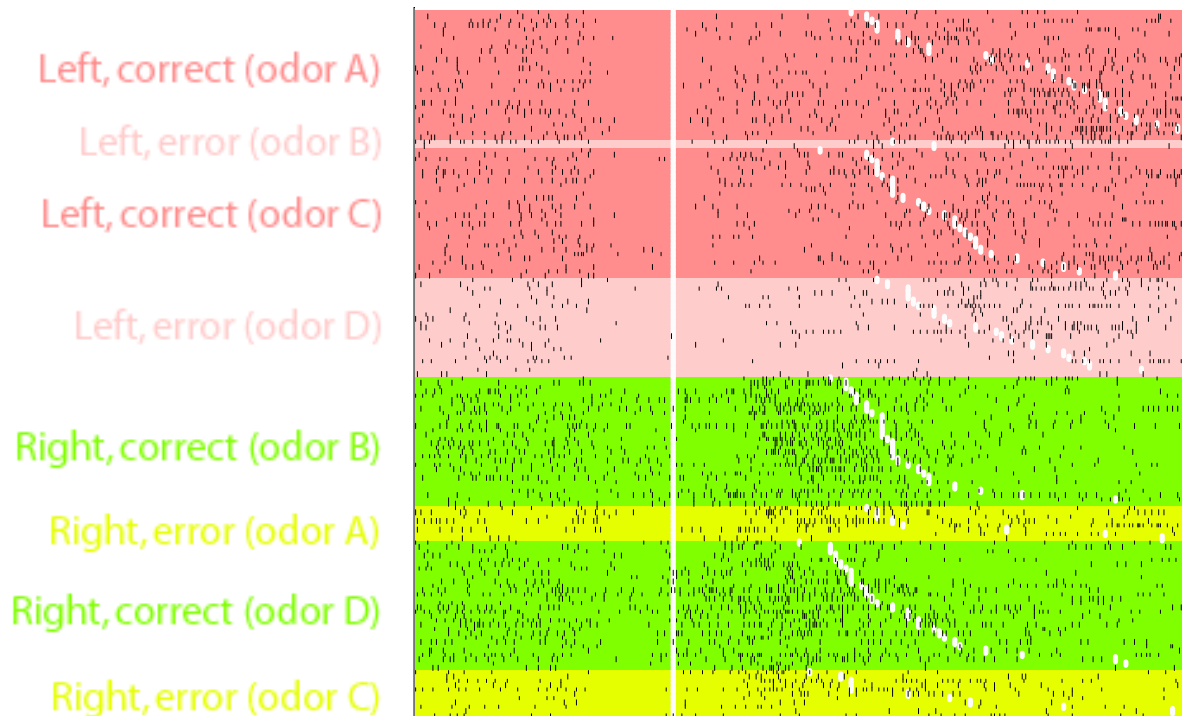
# Behavioral performance



# What neuronal activity might we expect to observe?

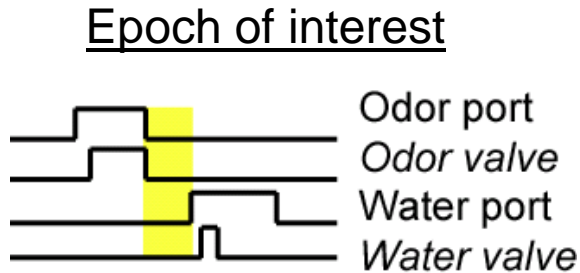
- Motor production: Activity selective for left vs. right during movement
- Motor planning: Direction selectivity preceding movement
- Decision-making: Activity representing the current stimulus and the upcoming motor plan

# Direction selectivity during movement



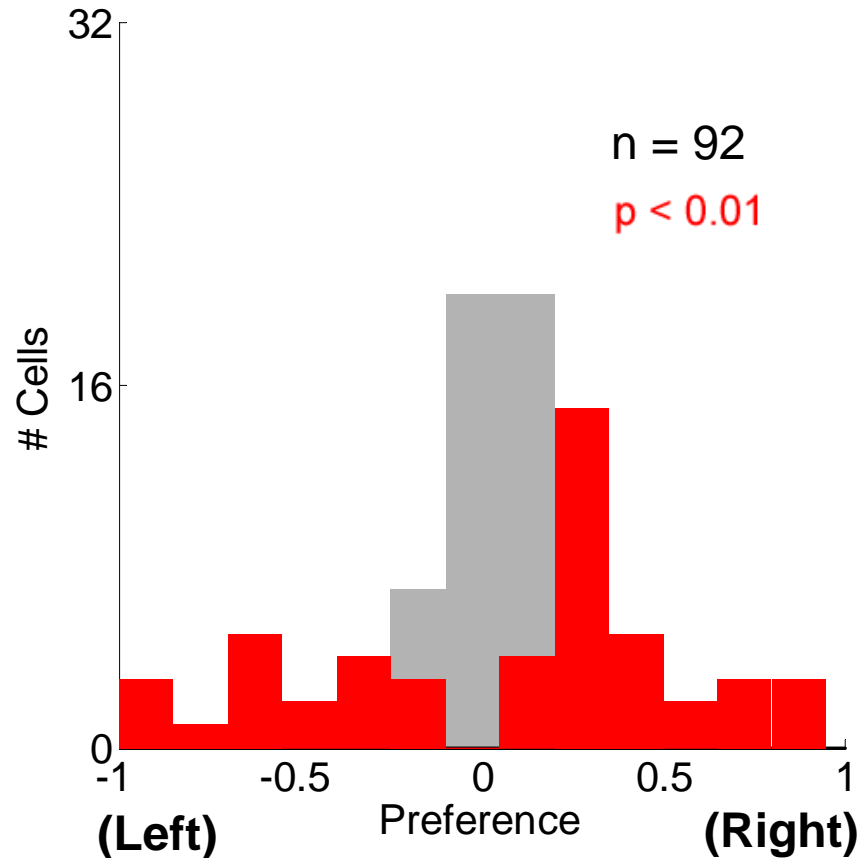
Left, correct  
Left, error  
Right, correct  
Right, error

# Movement preference across population

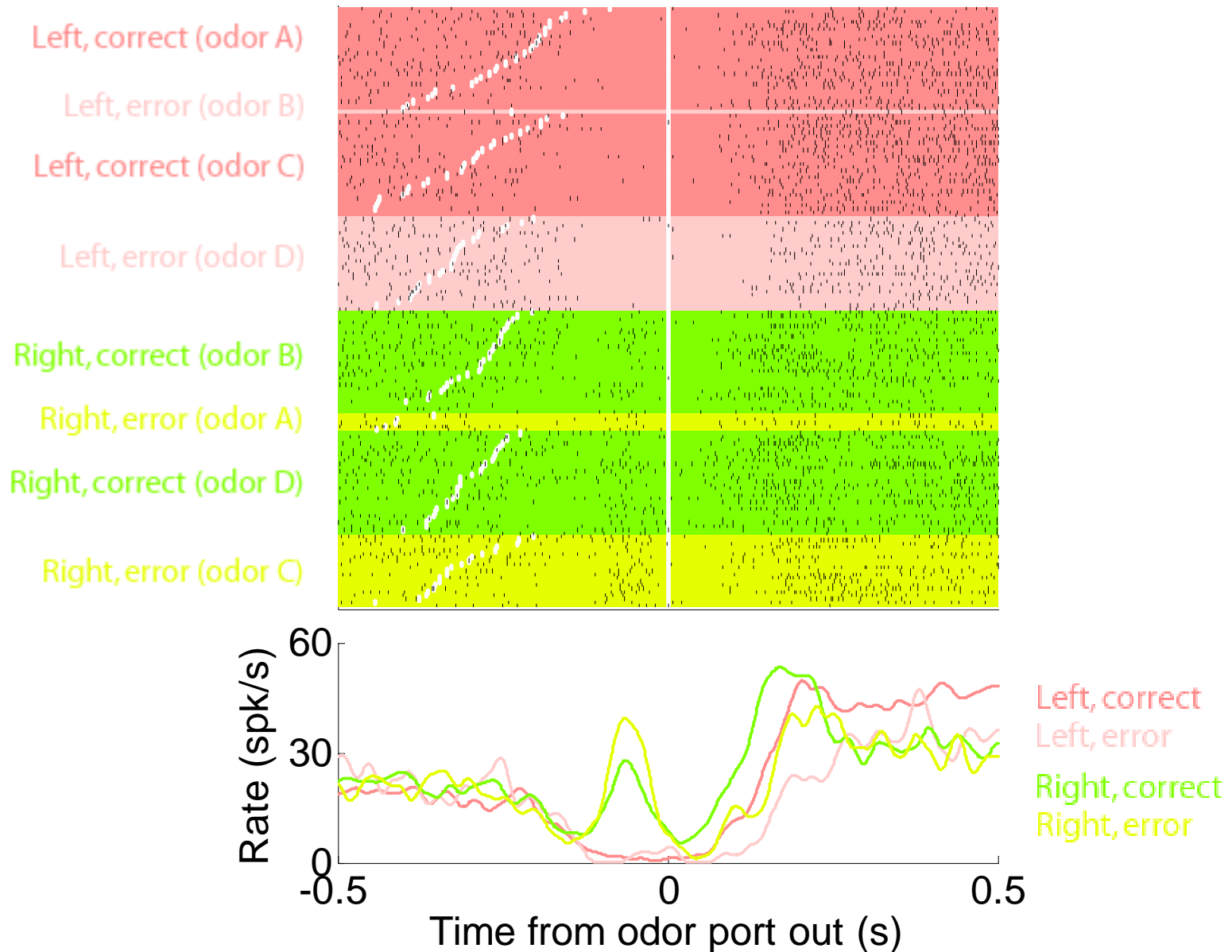


Calculate preference for left vs. right choice, independent of odor or correctness:

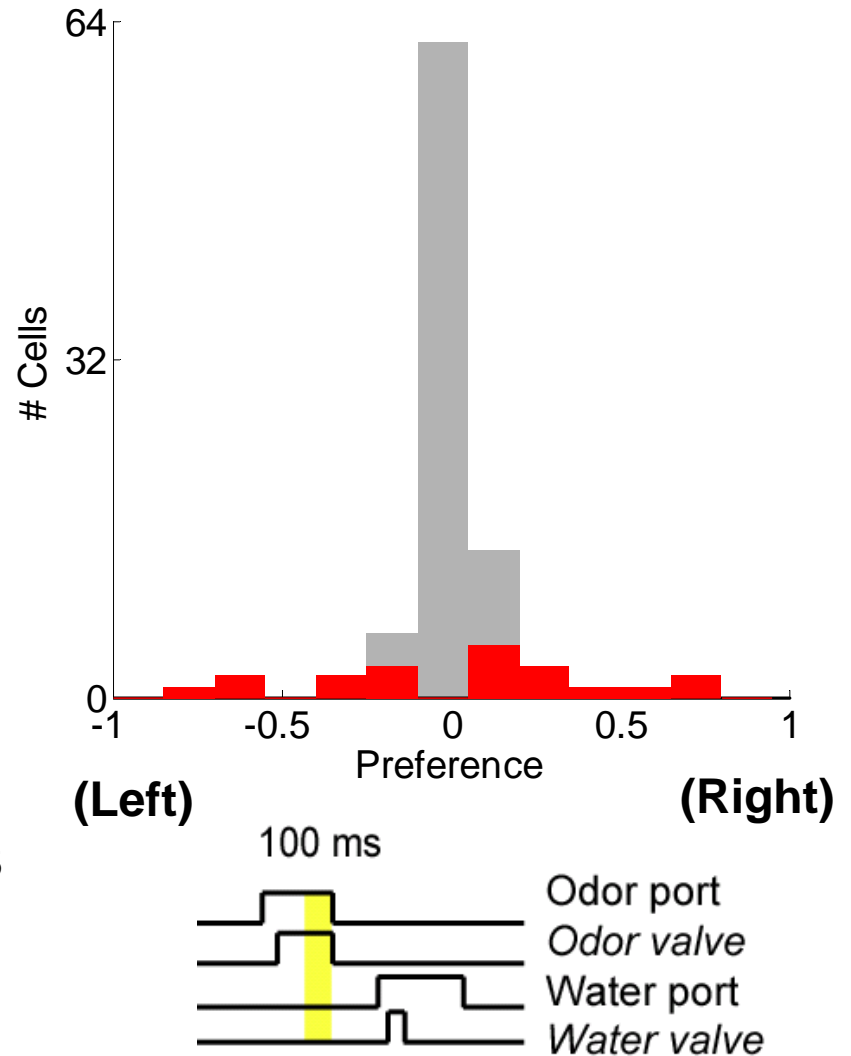
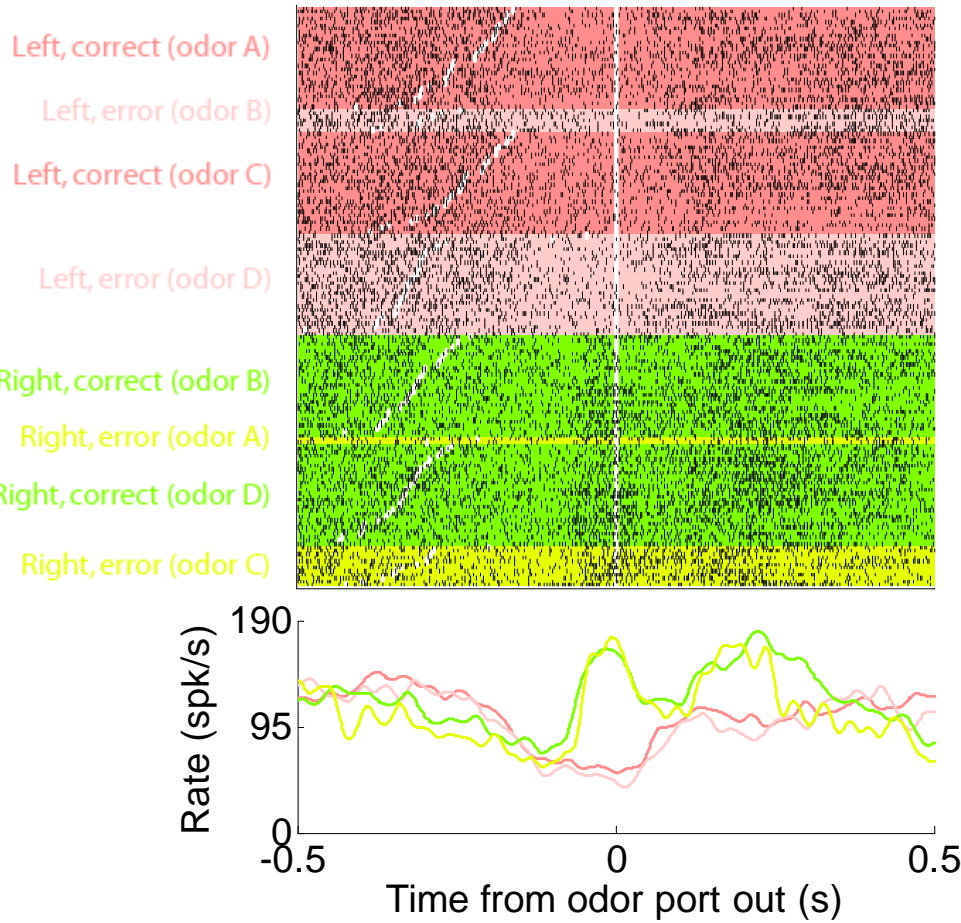
$$\text{Preference} = 2 * (\text{ROC} - 0.5)$$



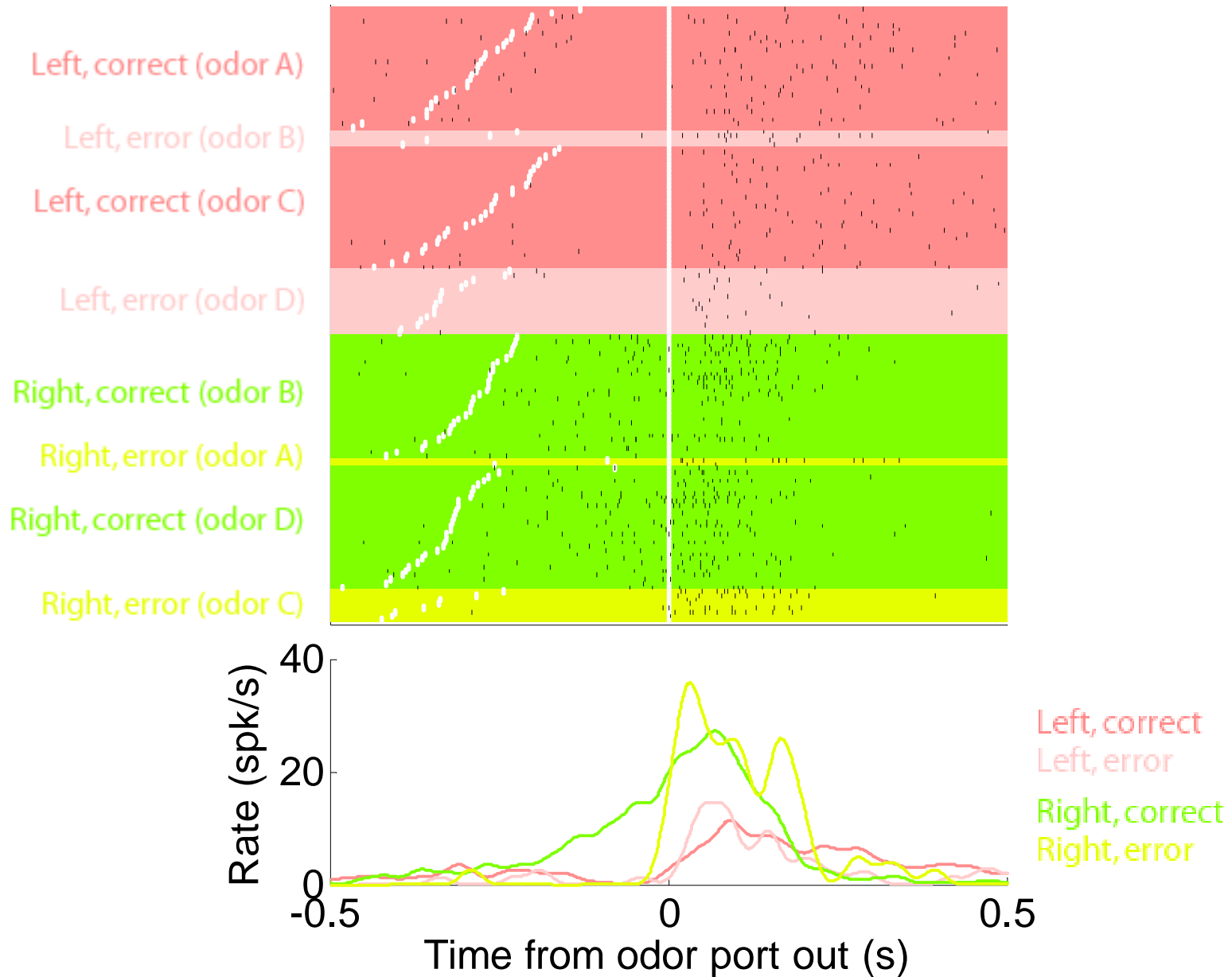
# Choice-prediction in SC



# Choice-prediction across population



# Conjunction of odor and choice



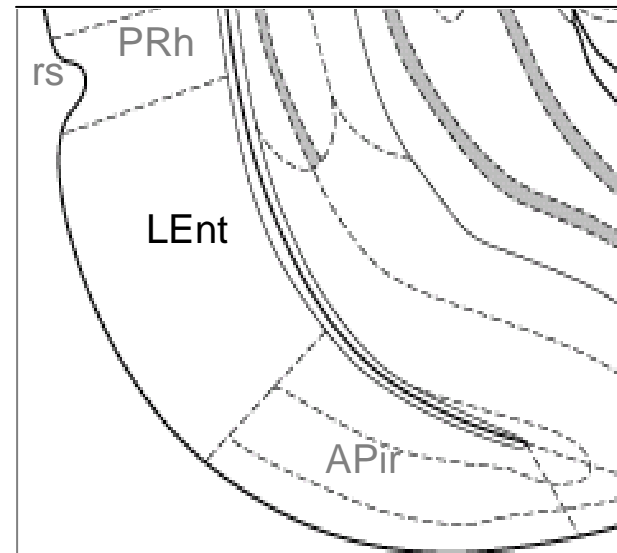
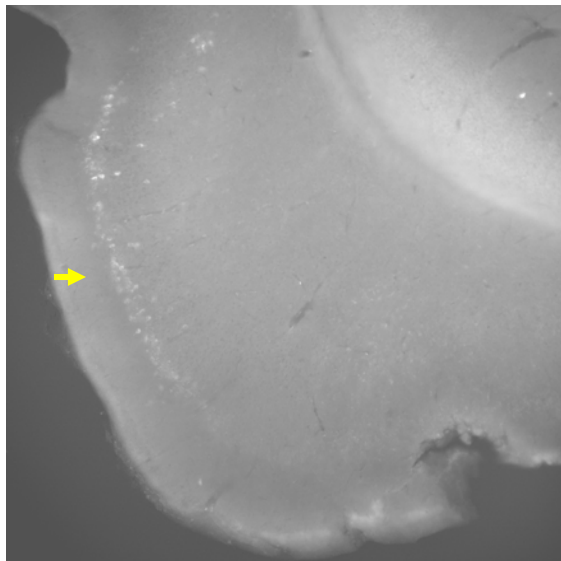
# Where is SC in the decision-making circuit?

- 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: Cholera toxin 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



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The End