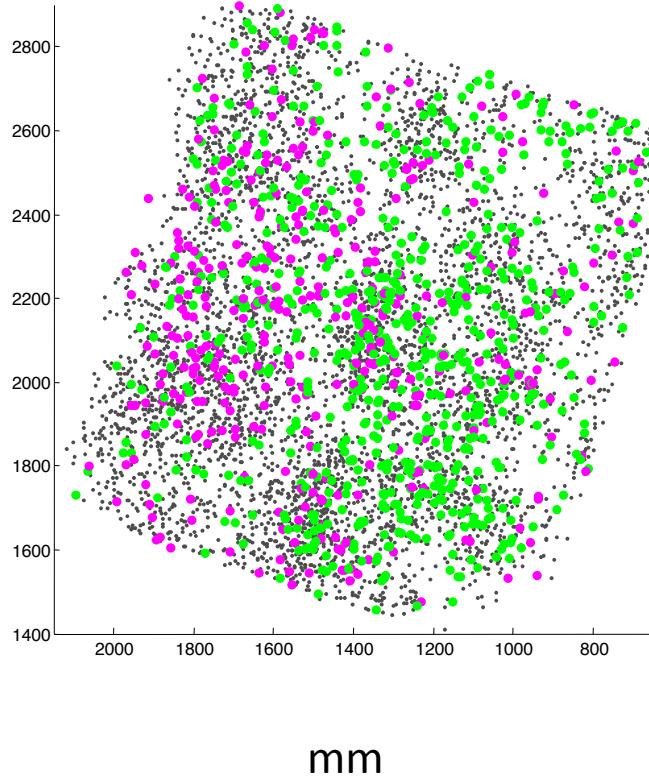
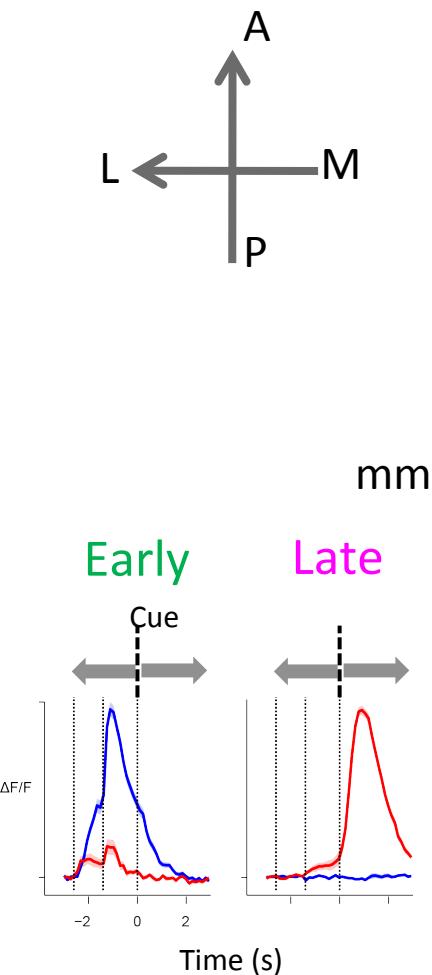


Goals

- Frontal cortical neurons encode diverse sensory/motor/memory information.
 - How do these responses organize in space?
- “Persistent activity” has been observed in many cortical areas, including ALM, FOF (vM1), mPFC etc.
 - Is persistent activity widely distributed in frontal cortex or is there a spatial hot spot?
 - What information is encoded by persistent activity?

Pilot results:

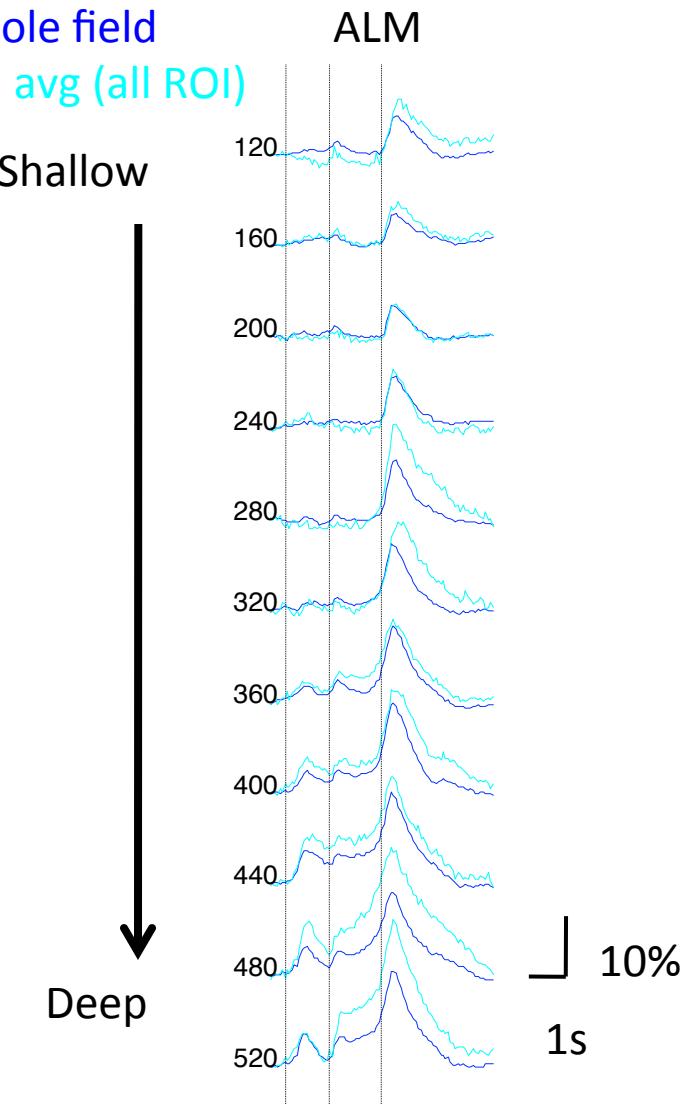
Spatial/layer topography of response dynamics



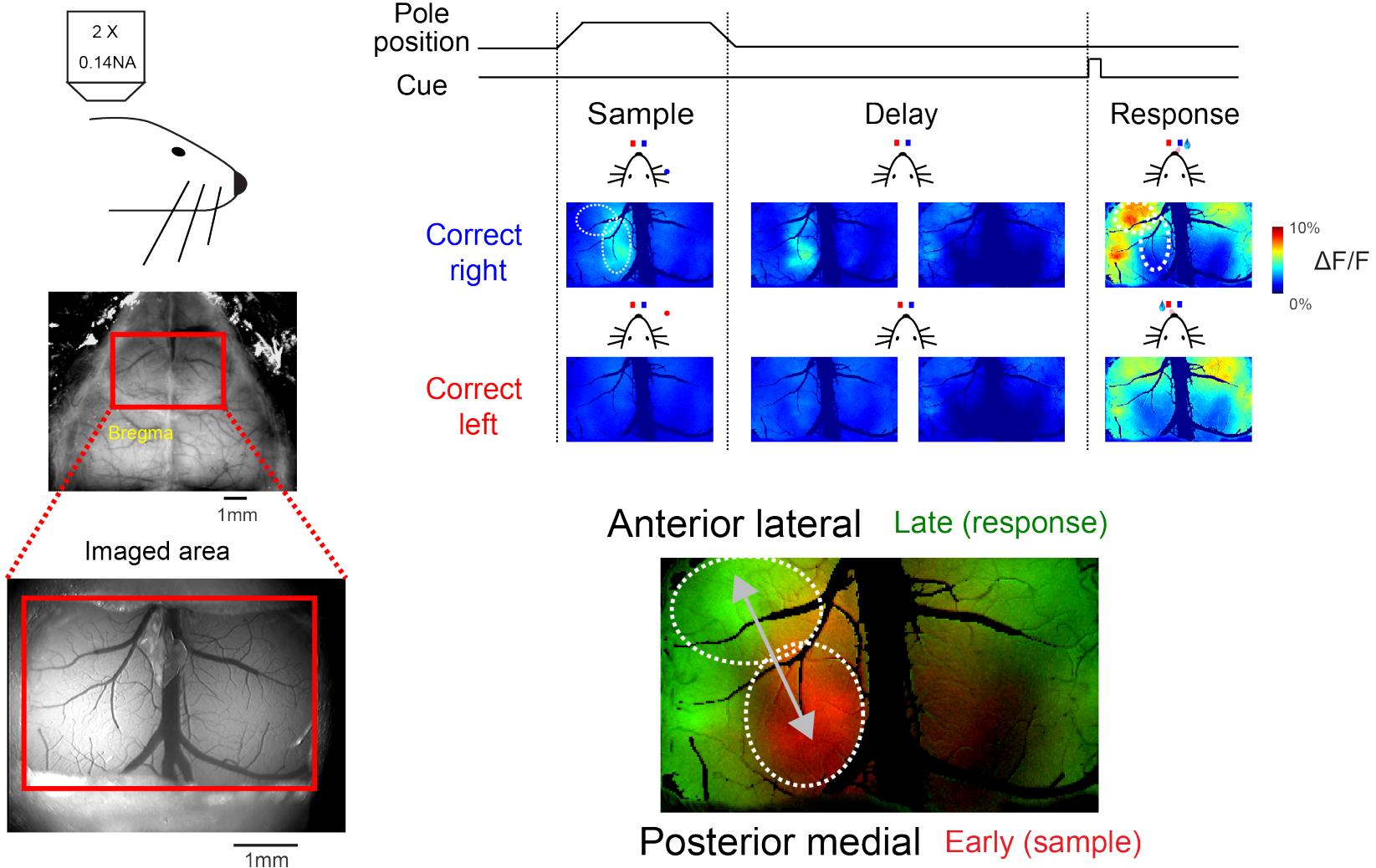
Whole field
ROI avg (all ROI)

Shallow

Deep

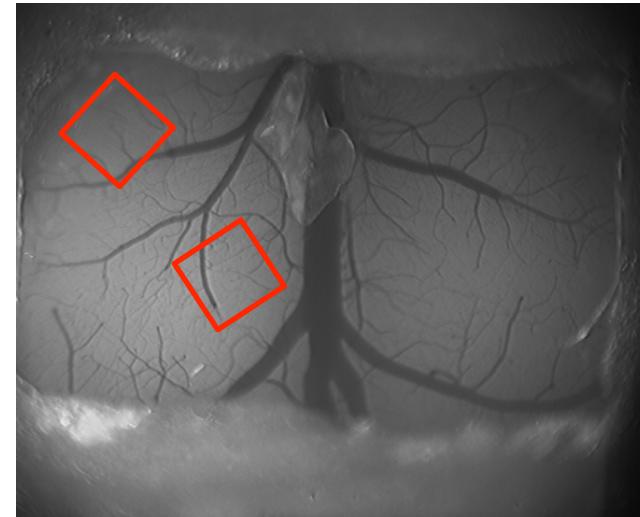
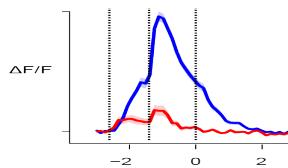


Spatial topography of response latency is captured by wide field [Ca] imaging



High resolution 2P imaging in defined area

- 3s delay period
- Enough error trials to distinguish sensory v.s. motor coding
- 3 animals, ~8500 cells, 100-600 μm
- GP4.3 (GCaMP6s transgenic mouse)



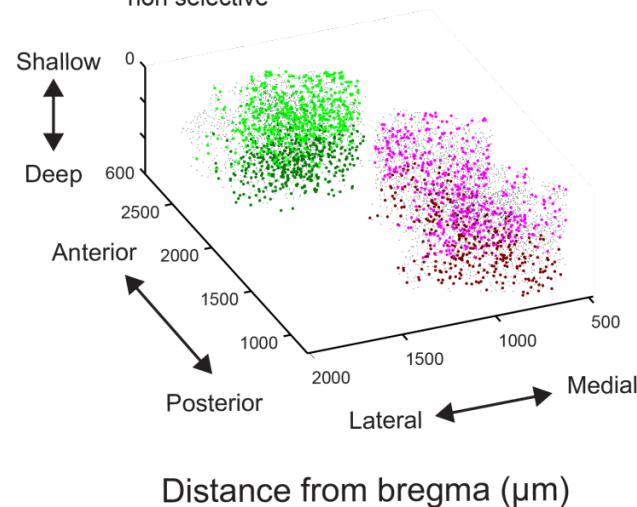
Anterior lateral, shallow ($z < 400\mu\text{m}$)

Anterior lateral deep ($z > 400\mu\text{m}$)

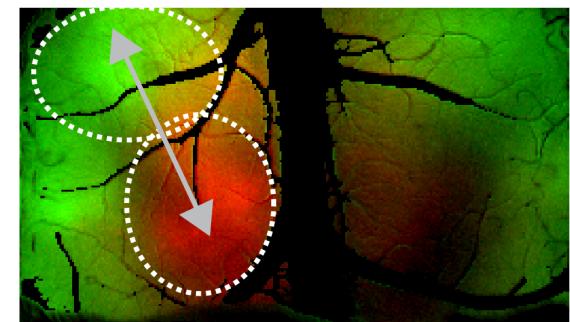
Posterior medial shallow ($z < 400\mu\text{m}$)

Posterior medial deep ($z > 400\mu\text{m}$)

non selective



Anterior lateral Late (response)



Posterior medial Early (sample)

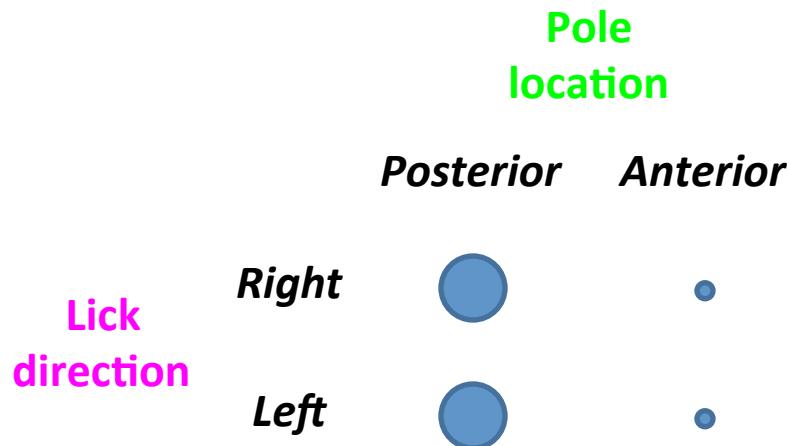
Analysis of error trials

Posterior *Anterior*



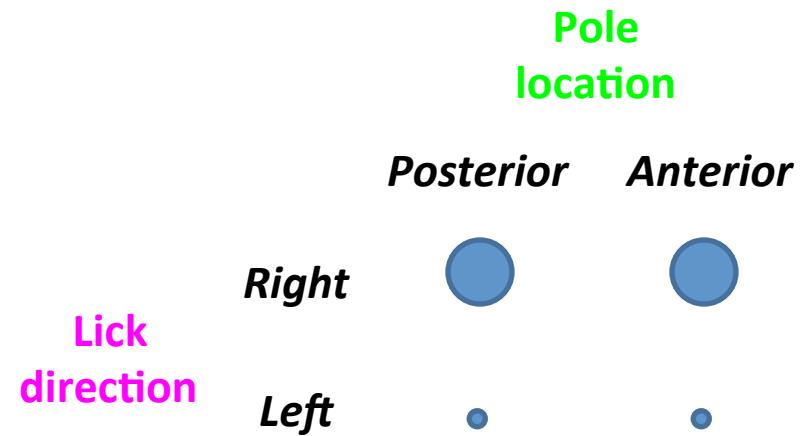
	<i>Right</i>	<i>correct</i>	<i>error</i>
<i>Left</i>		<i>error</i>	<i>correct</i>

Pole location cell



2-way ANOVA
Main effect: Pole location

Lick direction cell

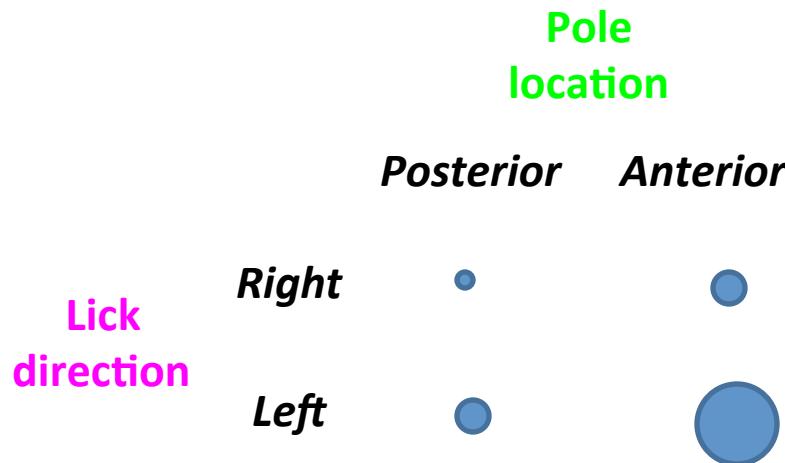


2-way ANOVA
Main effect: Lick direction

Analysis of error trials

	<i>Posterior</i>	<i>Anterior</i>
<i>Right</i>	correct	error
<i>Left</i>	error	correct

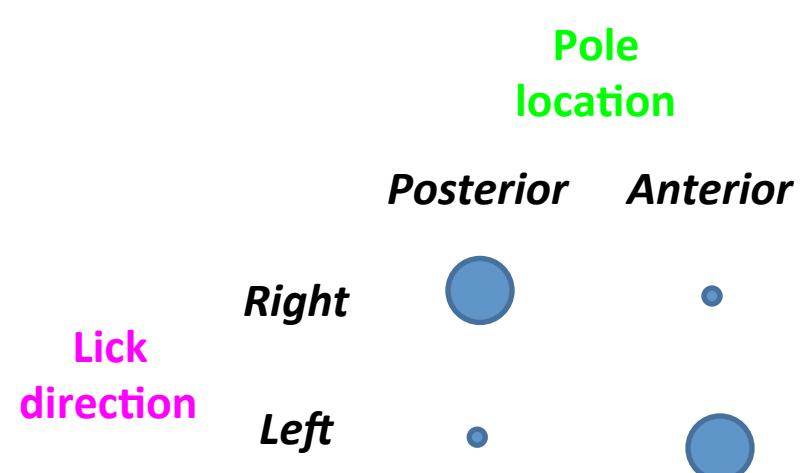
Mixed cell



2-way ANOVA

Main effect: both factors, maybe interact

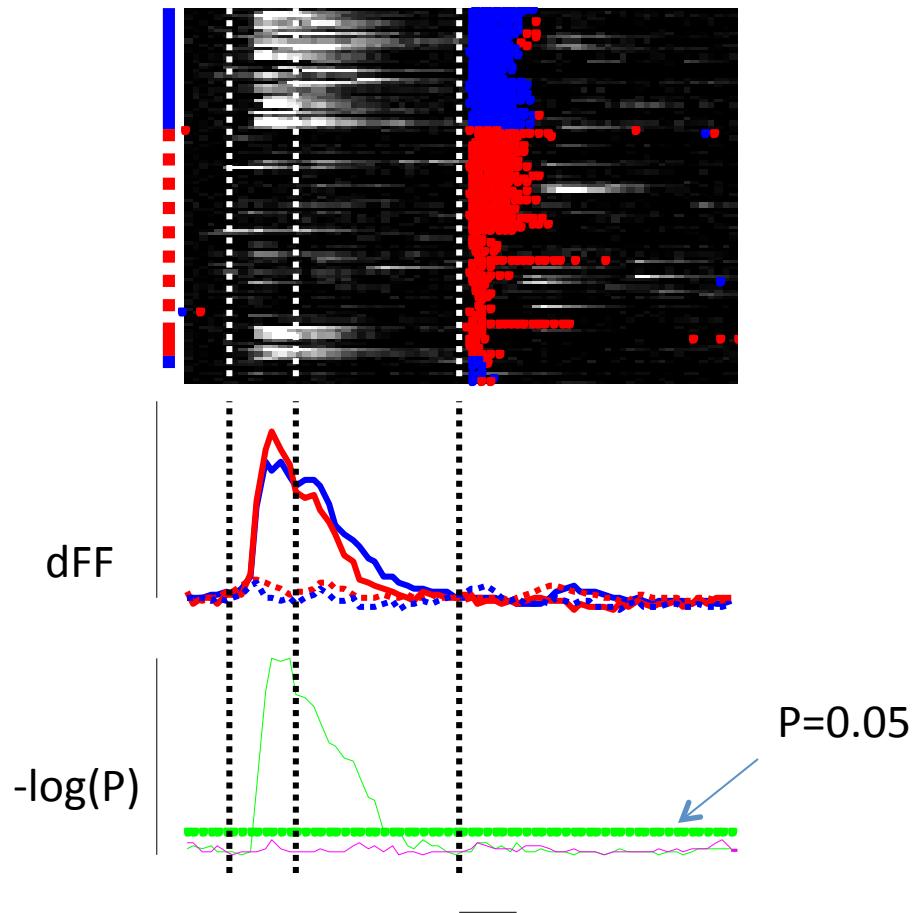
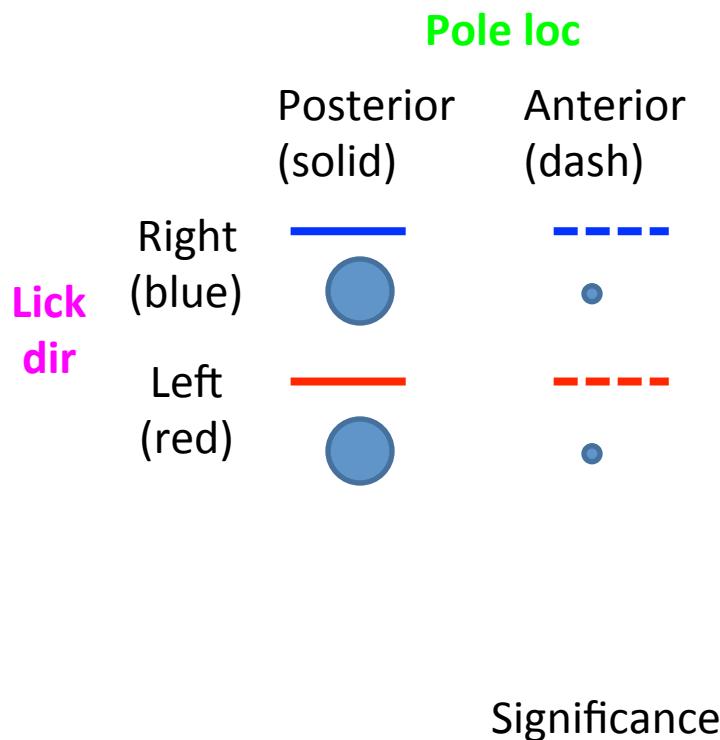
Water cell?



2-way ANOVA

Main effect: no effect both factors

Example: Pole location cell



Pole location
Lick direction

Pole loc

Posterior Anterior

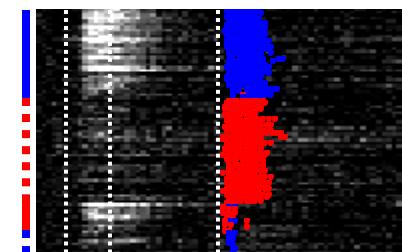
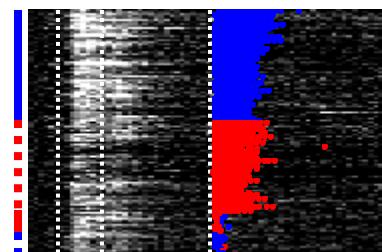
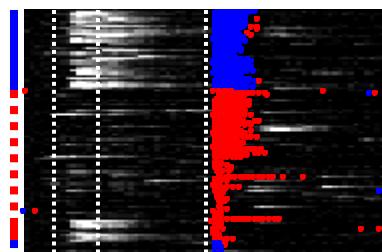
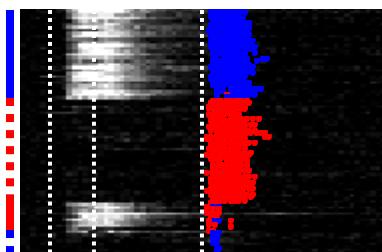
Right ————
—·—

Lick dir

Left ————
—·—

Pole location cells

--Sample



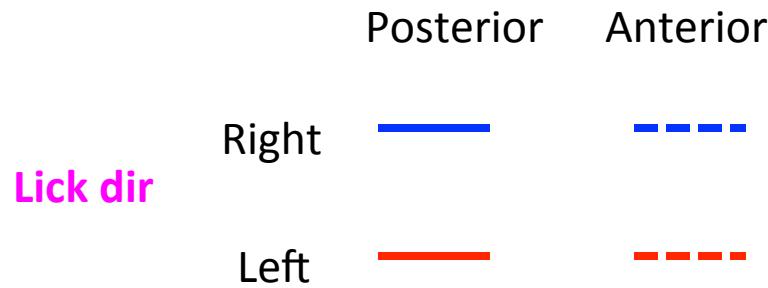
2163

4010

6778

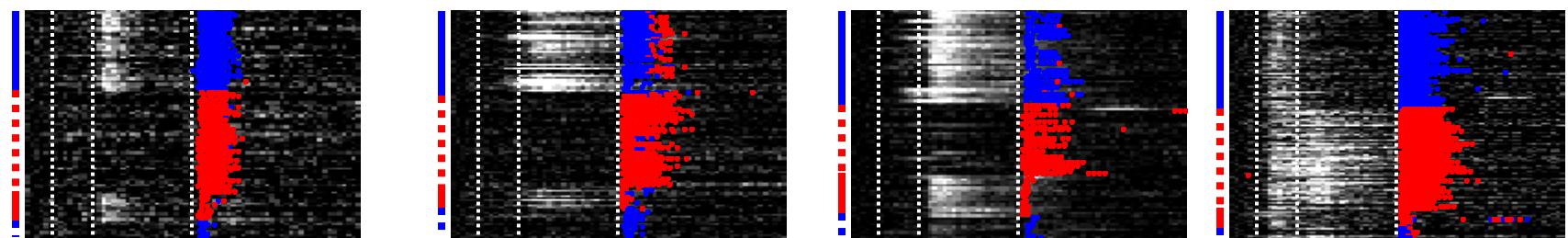
2235

Pole loc



Pole location cells

--Sample off/delay



dFF

-log(P)

4646

vM1, 550um

3280

vM1, 370 um

440

ALM, 185 um

7039

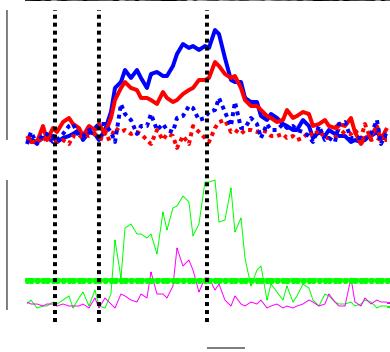
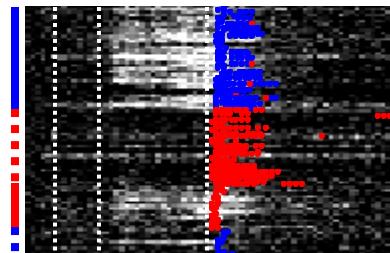
vM1, 570um

Pole loc

Posterior Anterior

Lick dir

Right ————
Left ————



446

ALM 185

888
ALM 290

5402

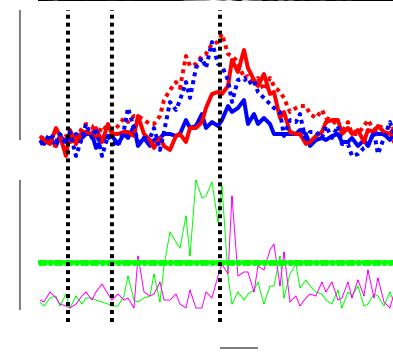
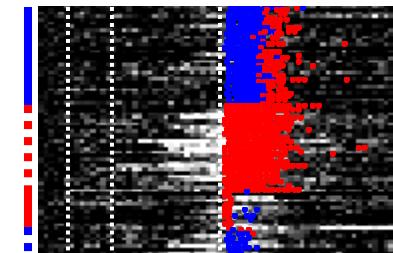
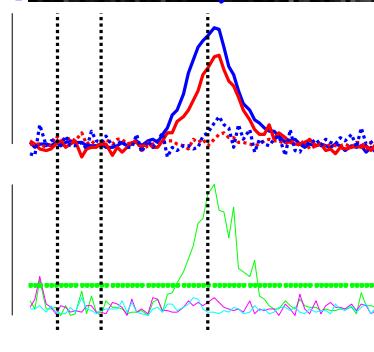
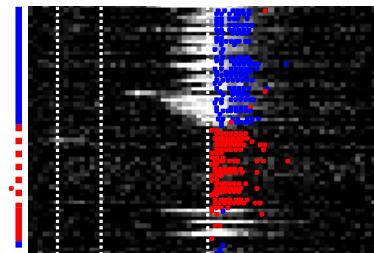
ALM 140

3210

vM1 320

Pole location cells

--late delay

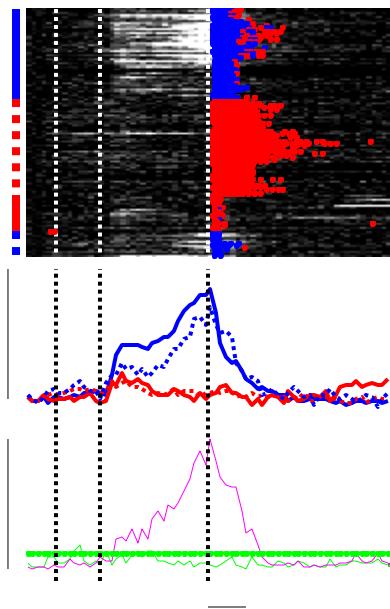


Pole loc

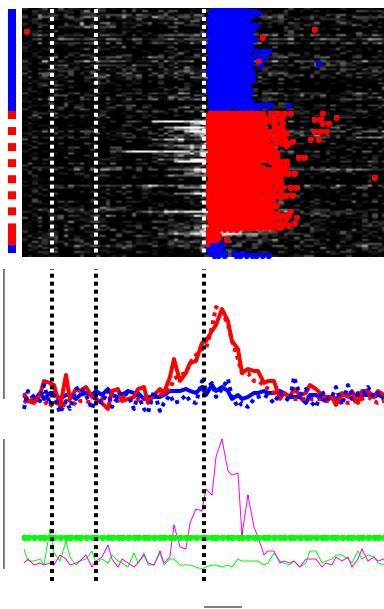
Posterior Anterior

Lick dir

Right ————
Left ————



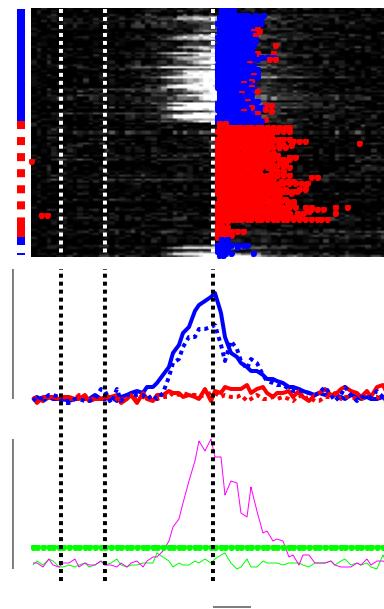
1965



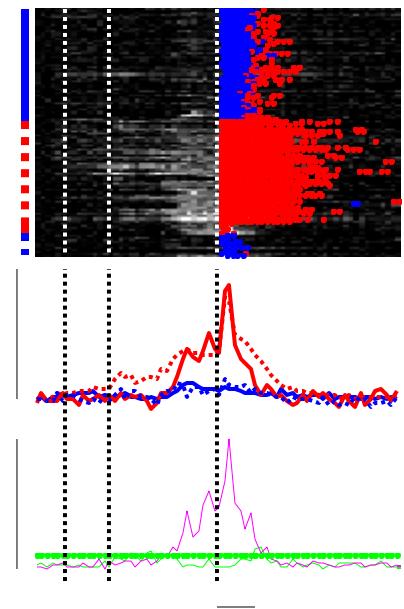
643

Lick direction cell

--delay



1561



1767

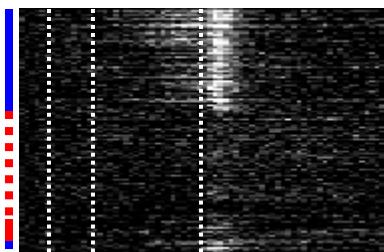
Pole loc

Posterior Anterior

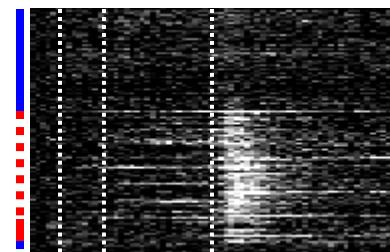
Right ———

Lick dir

Left ——



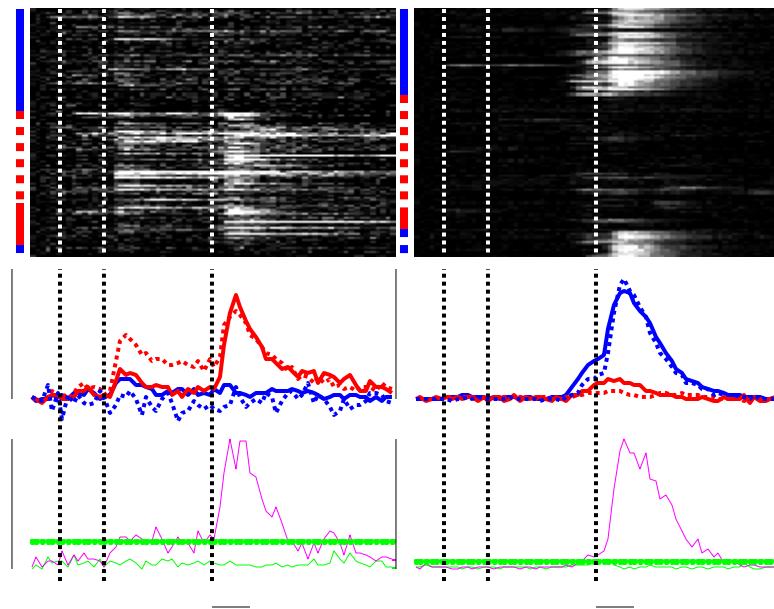
1896



1859

Lick direction cell

--early response



936

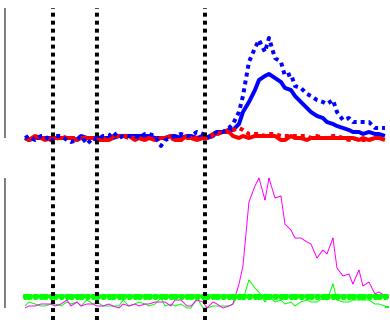
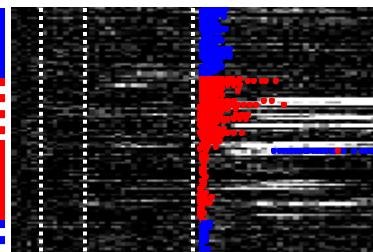
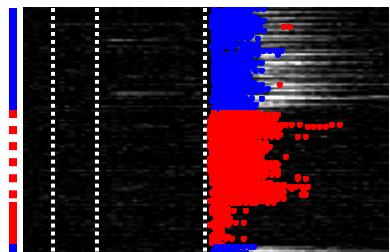
5387

Pole loc

Posterior Anterior

Lick dir

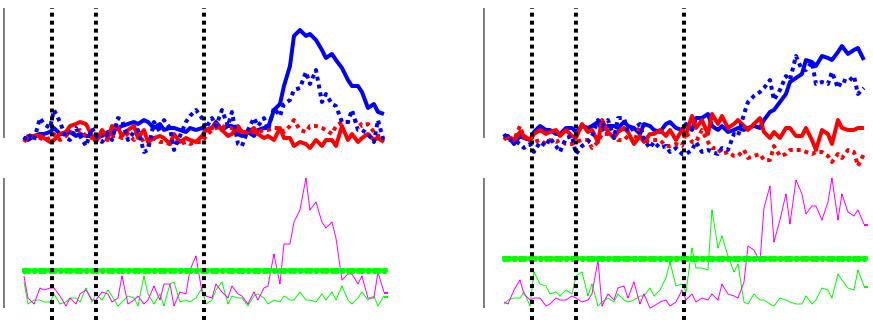
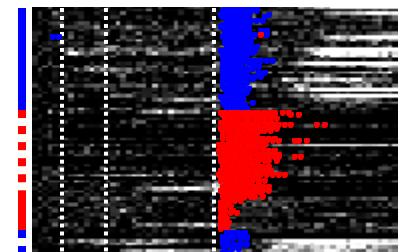
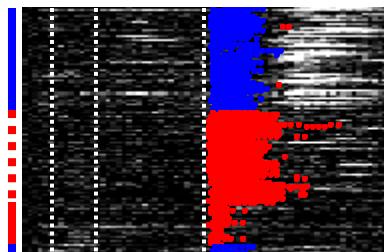
Right	—	---
Left	—	---



846

Lick direction

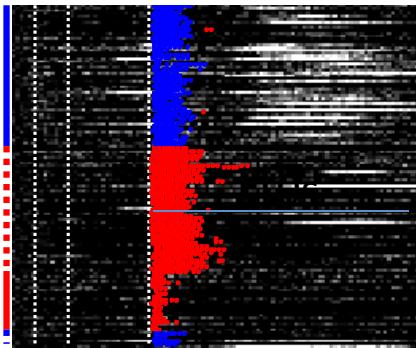
--late (lick off?)



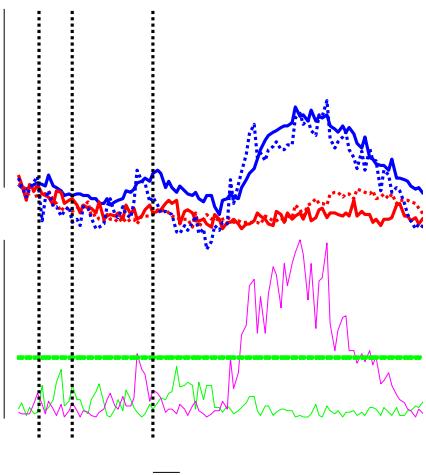
1412

936

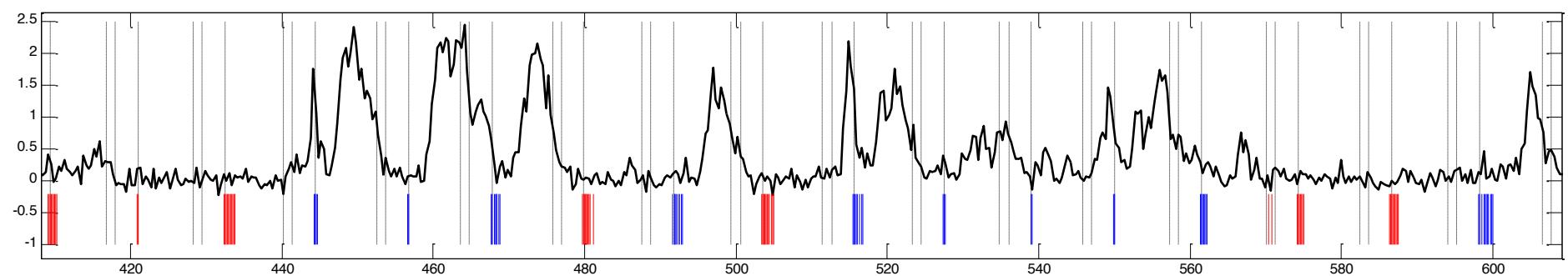
1227



Super late cell



831 (ALM, 290um)



•Movie

Sample

Delay

Response

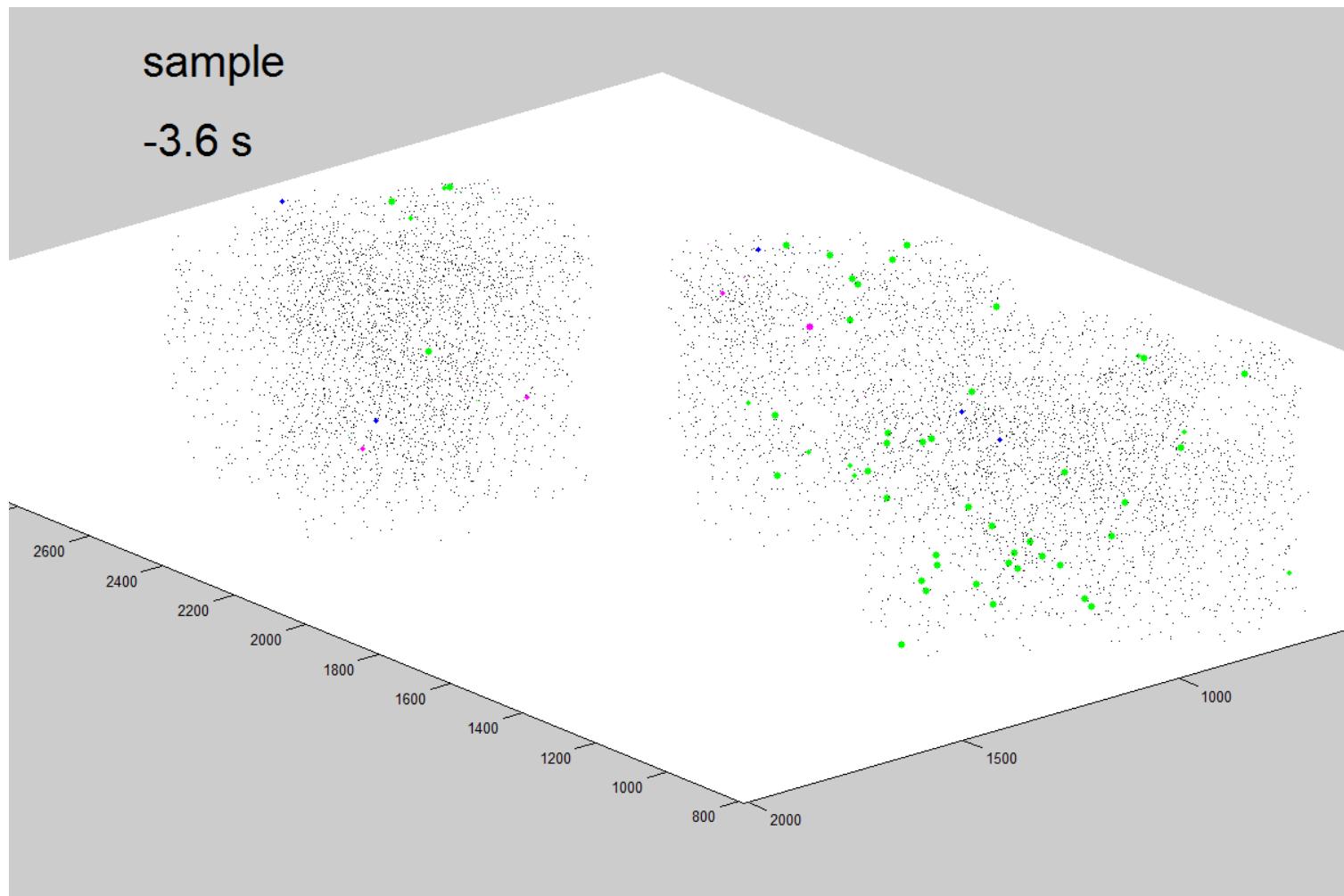
Pole location

Lick direction

mixed

sample

-3.6 s



Sample

Delay

Response

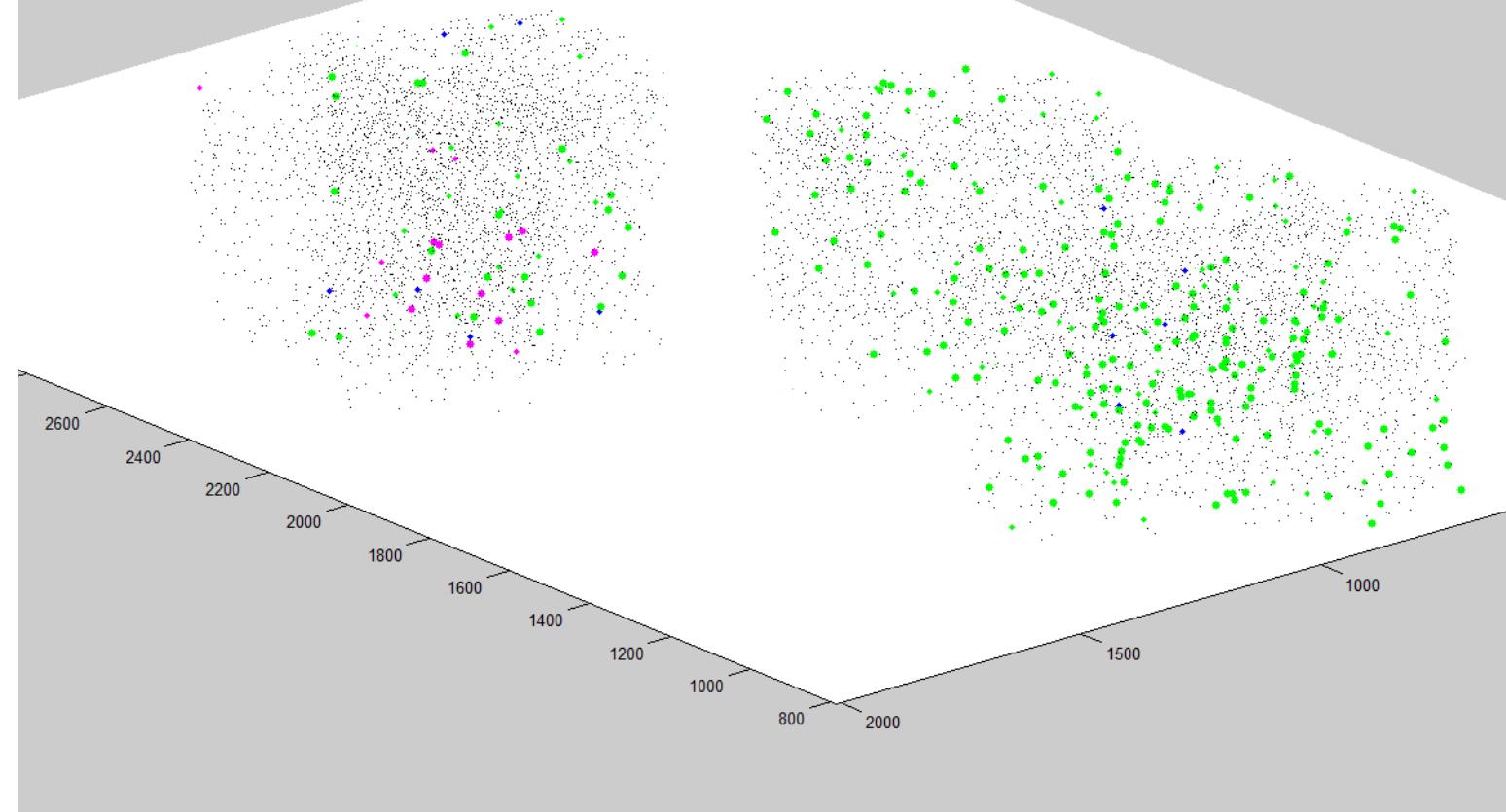
Pole location

Lick direction

mixed

delay

-2.4 s



Sample

Delay

Response

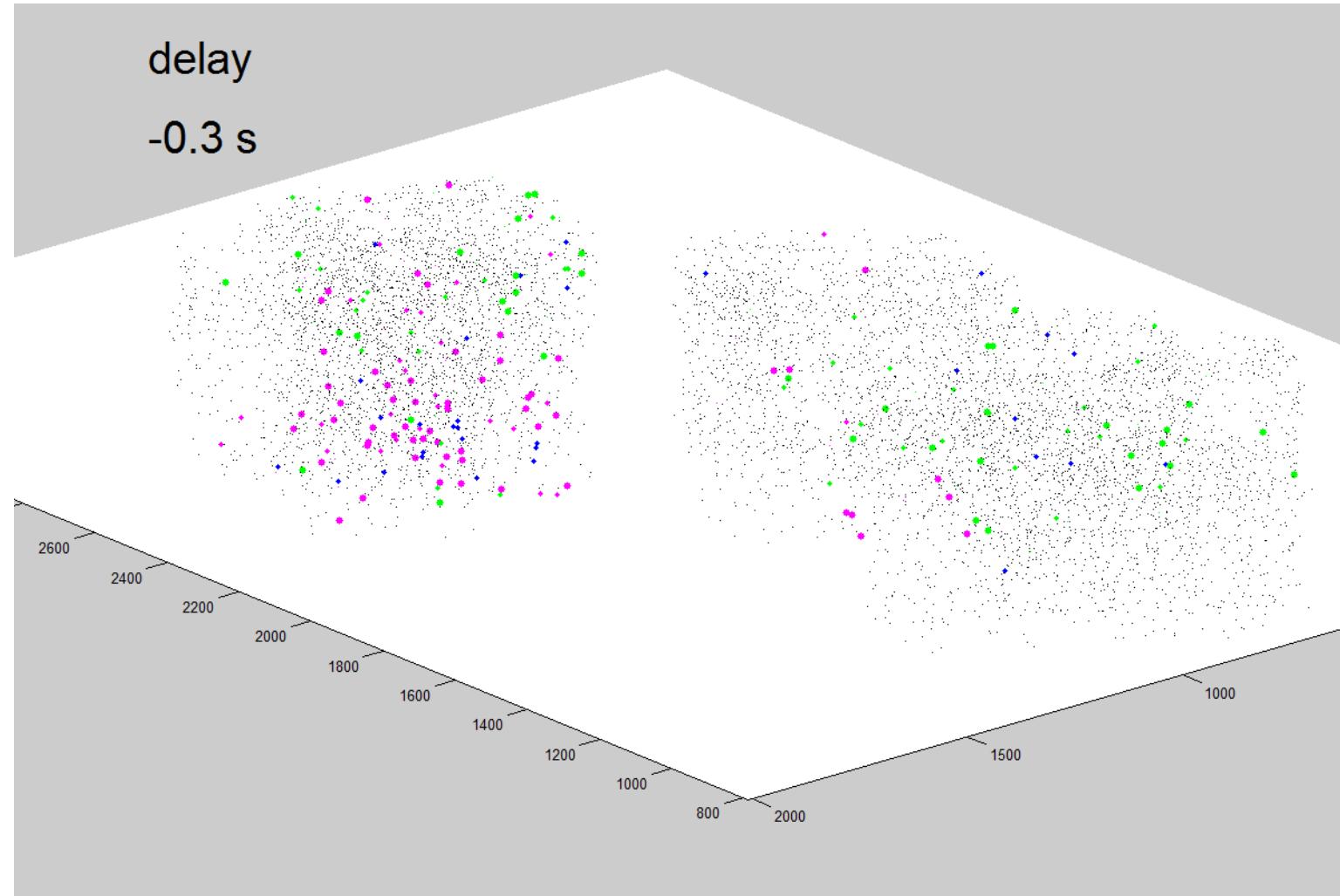
Pole location

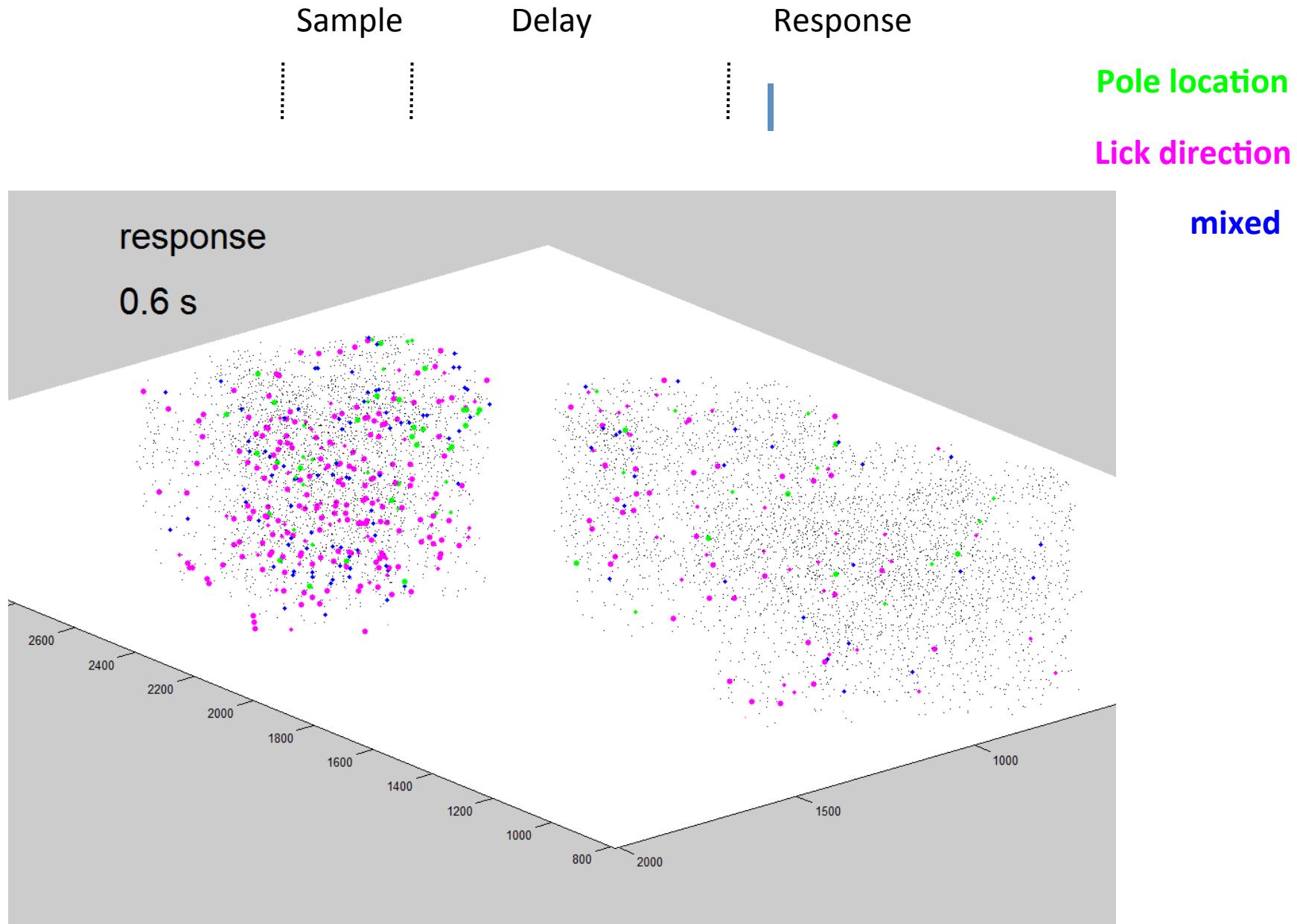
Lick direction

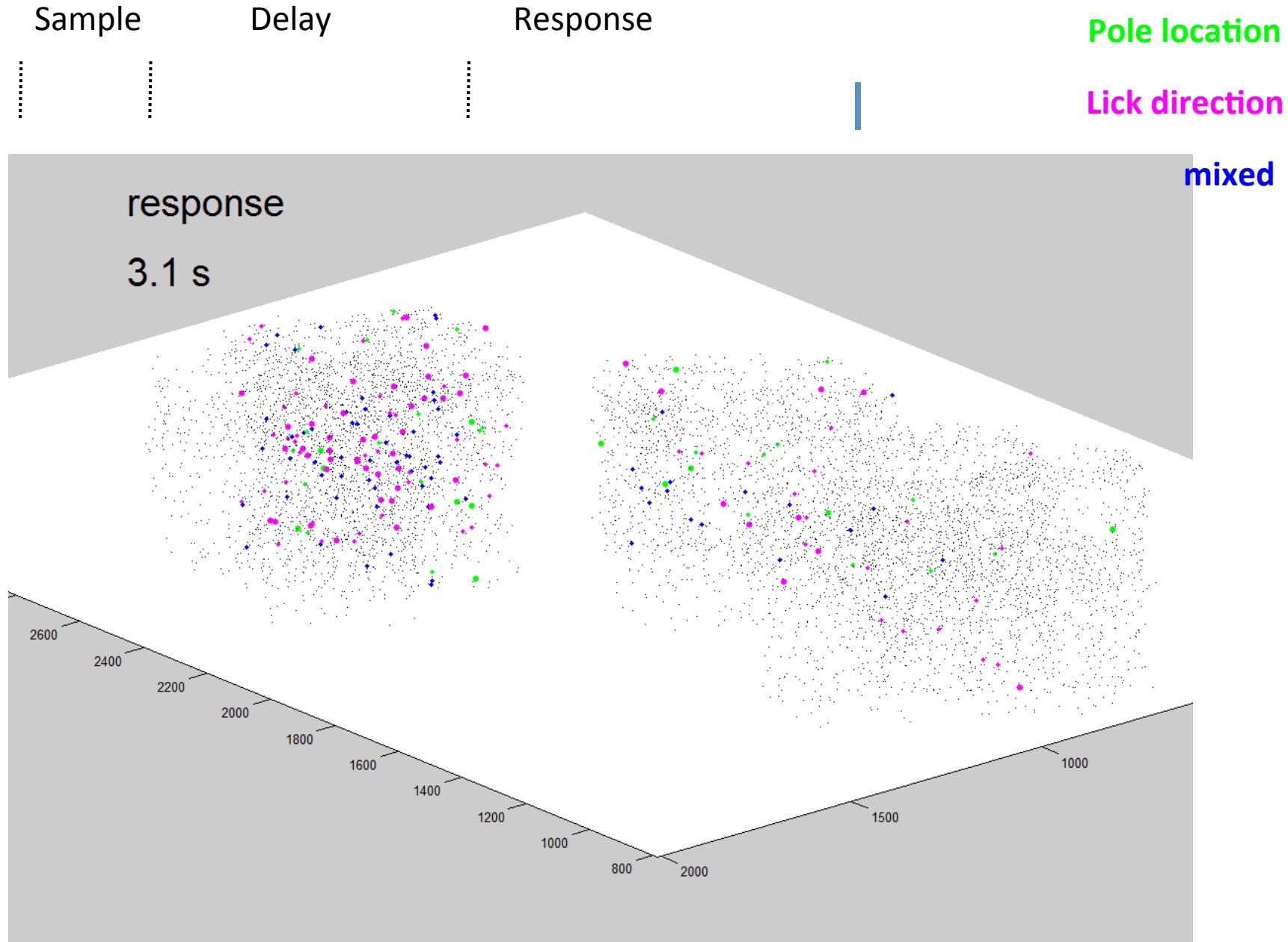
mixed

delay

-0.3 s



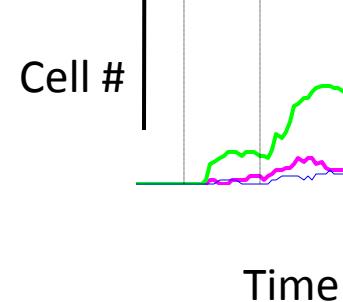




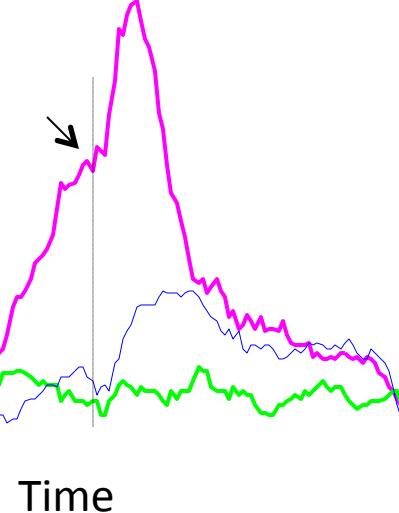
ALM superficial
 $<400 \text{ }\mu\text{m}$

Lick direction
Pole location
mix

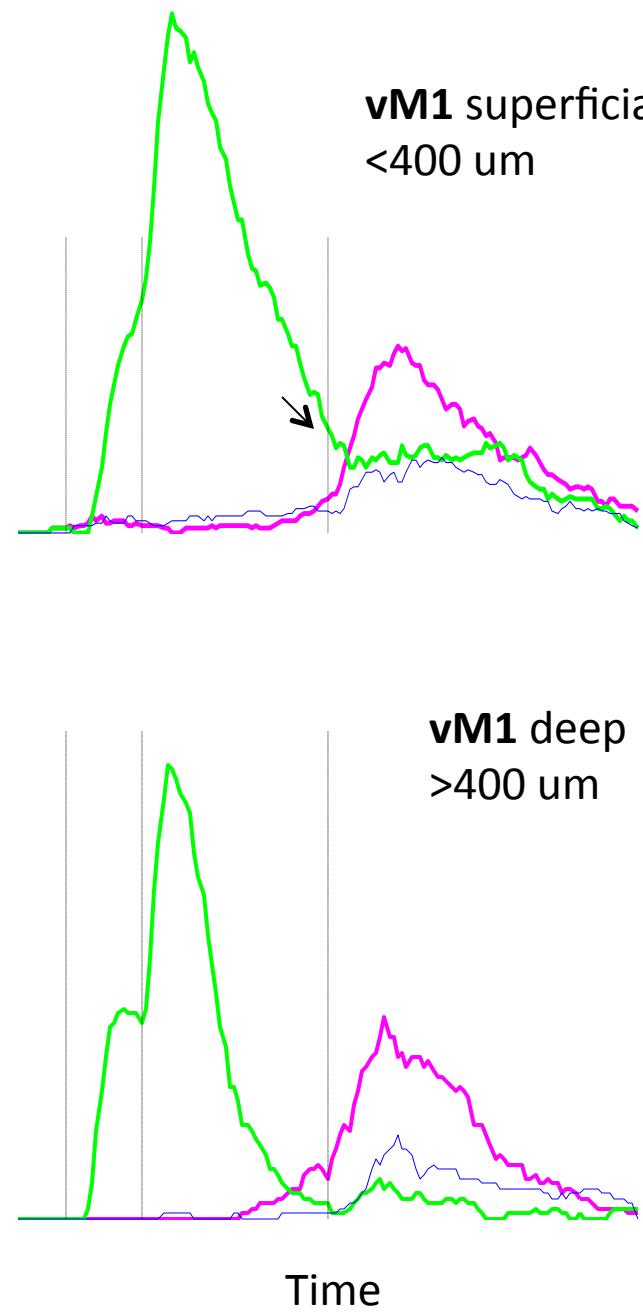
vM1 superficial
 $<400 \text{ }\mu\text{m}$



ALM deep
 $>400 \text{ }\mu\text{m}$



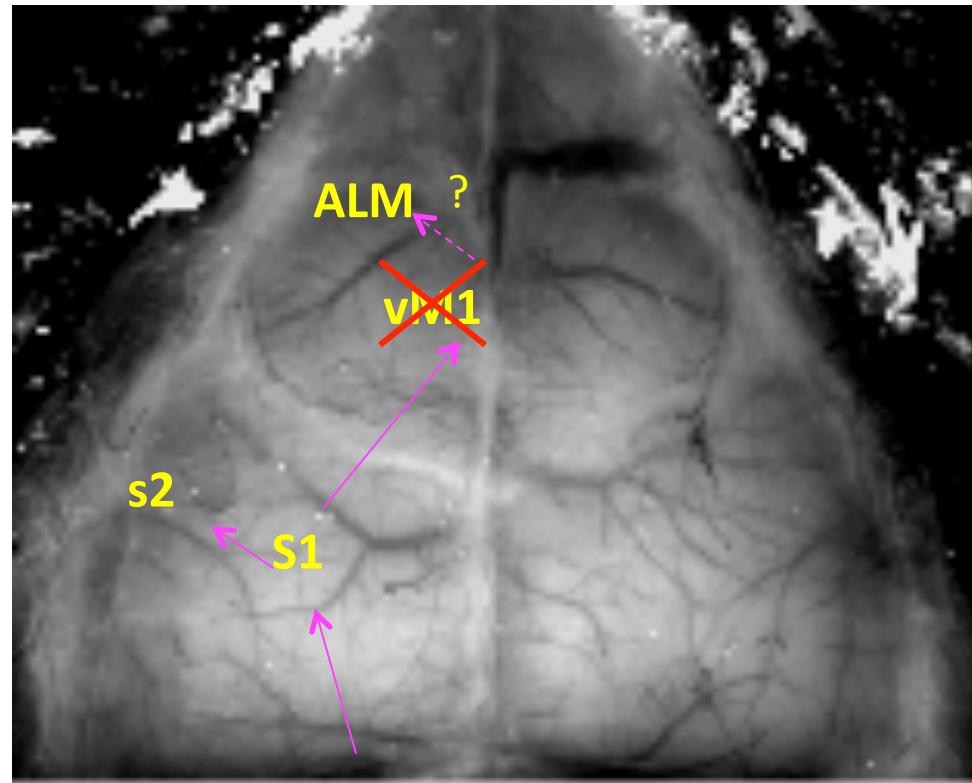
vM1 deep
 $>400 \text{ }\mu\text{m}$



Summary

- Information about both pole location and lick direction is remembered at single neuron level
- Pole location information is prominently represented by vM1 neurons
- Persistent activity predicting lick direction was observed most prominently in deep ALM
- Superficial ALM and vM1 neurons seem to maintain information about pole location through the end of delay period
- Many ALM neurons ‘remember’ the licked direction seconds after the last lick

Is vM1 essential for sensory information to drive behavior?



Touch

Standard contingency

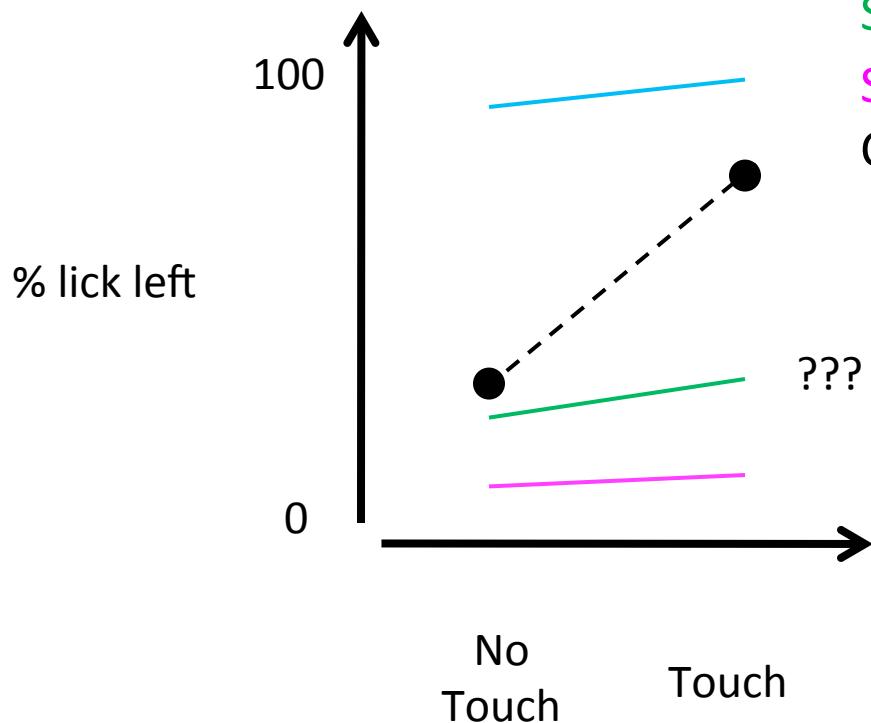


Reversed contingency



Expected result:

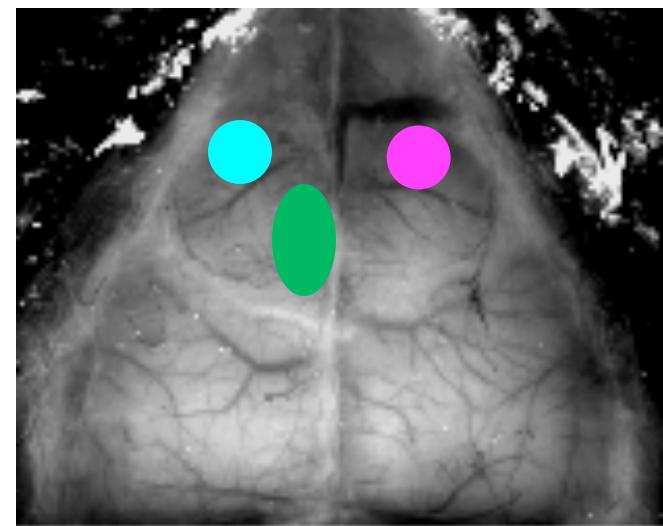
If silencing vM1 impairs
the sensation of touch



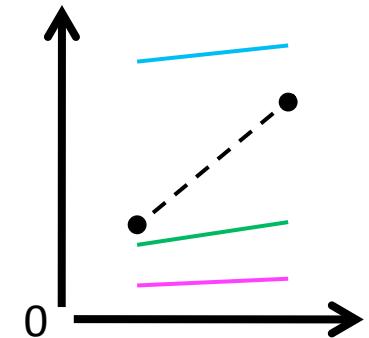
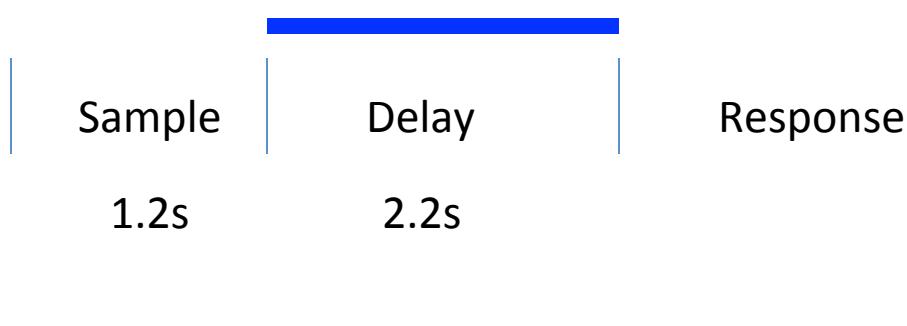
Reversed contingency



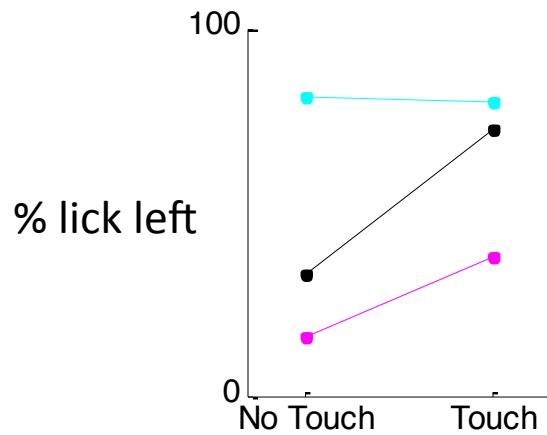
Silence left ALM
Silence left vM1
Silence right ALM
Control



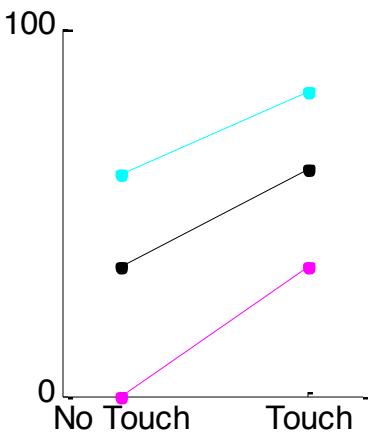
Silencing ALM produce expected effect



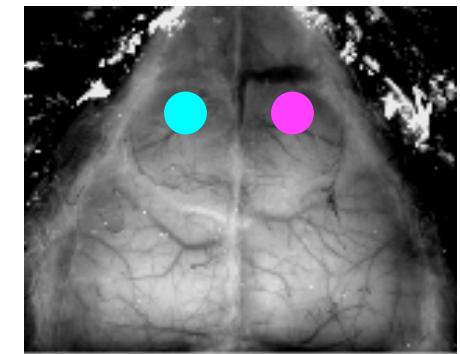
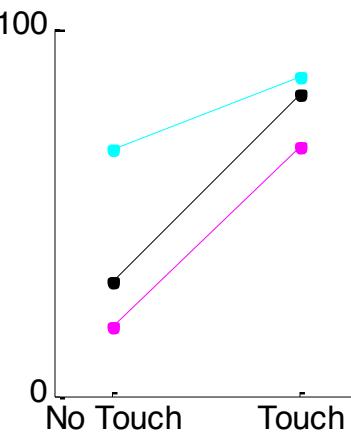
An 048



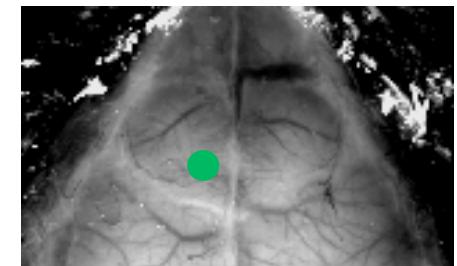
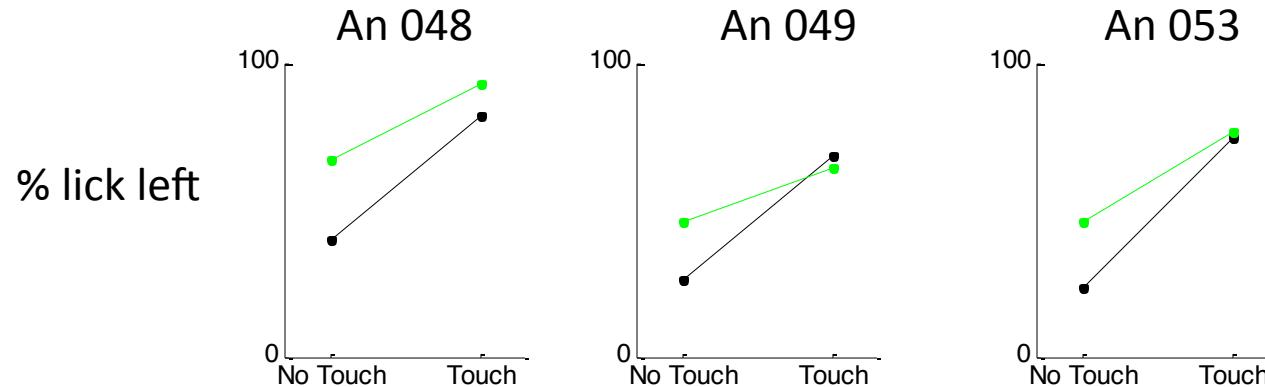
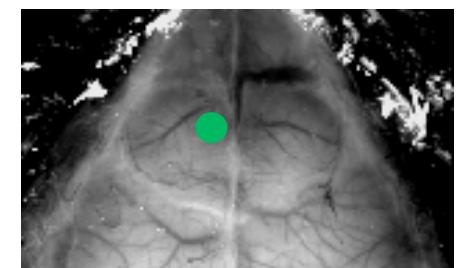
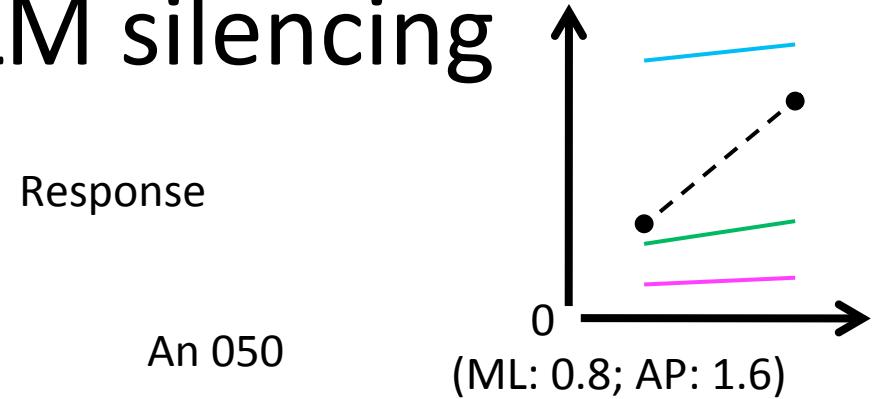
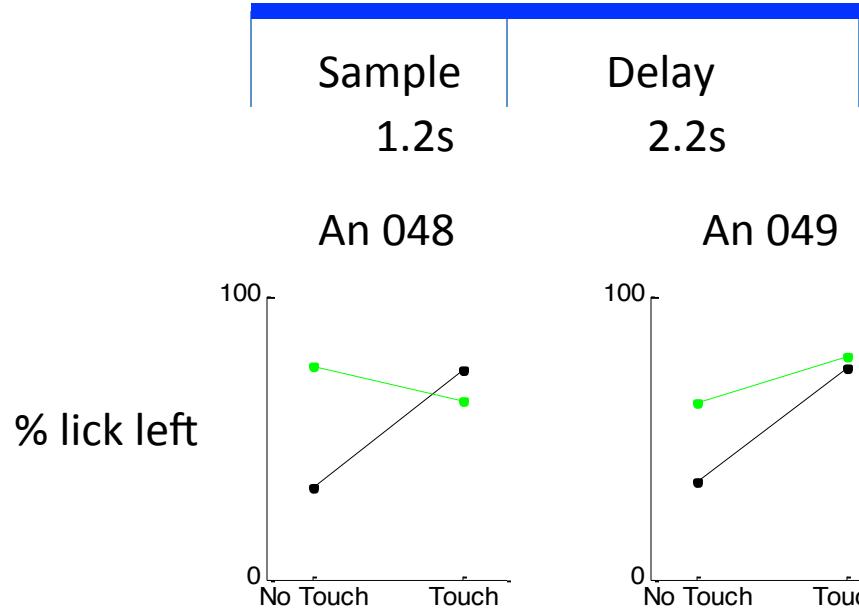
An 049



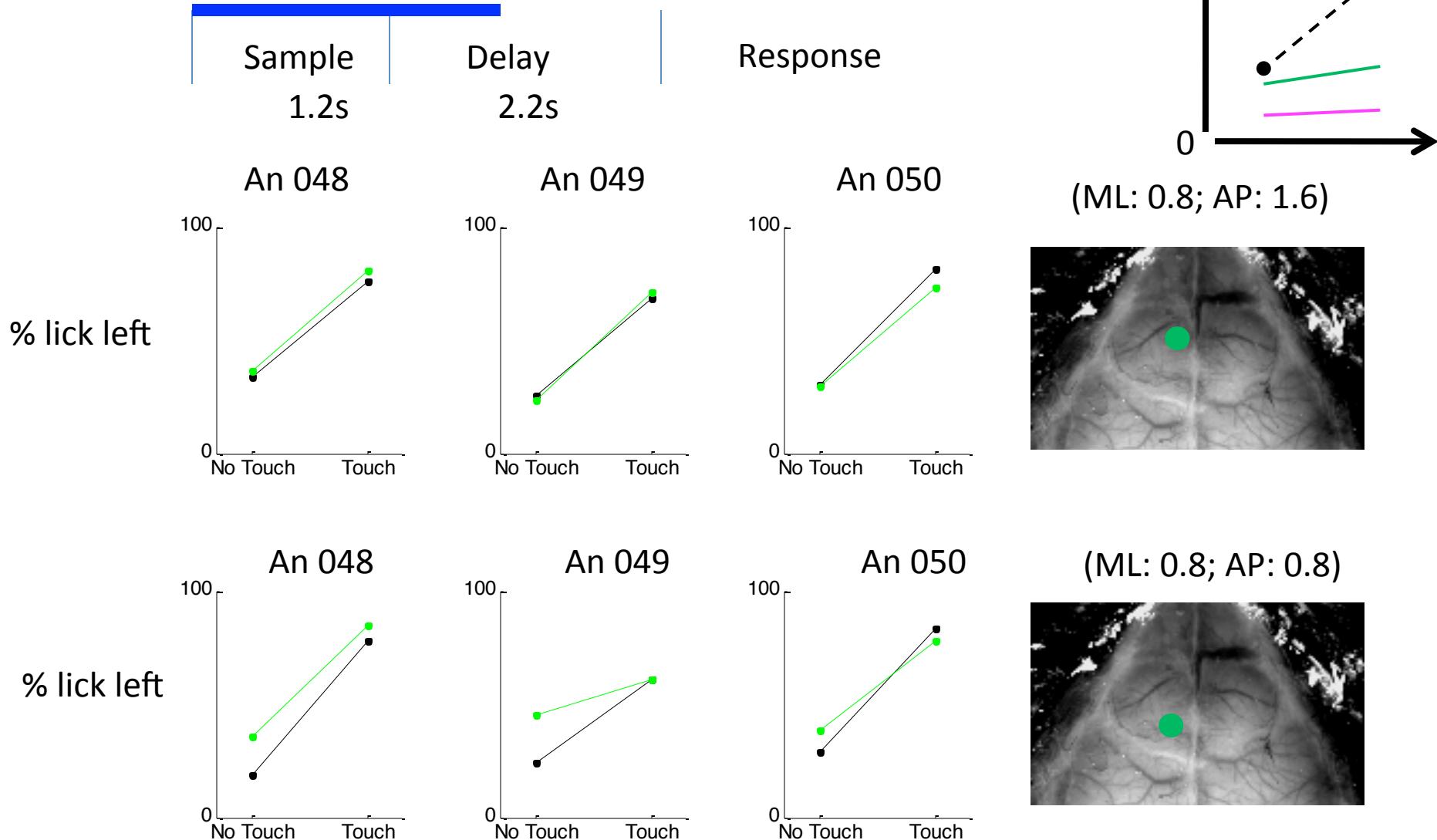
An 050



Silencing left vM1 throughout the task mimic left ALM silencing

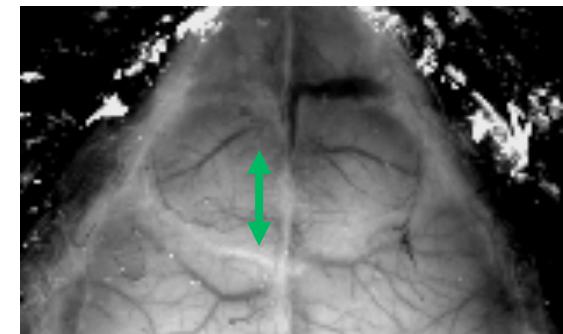
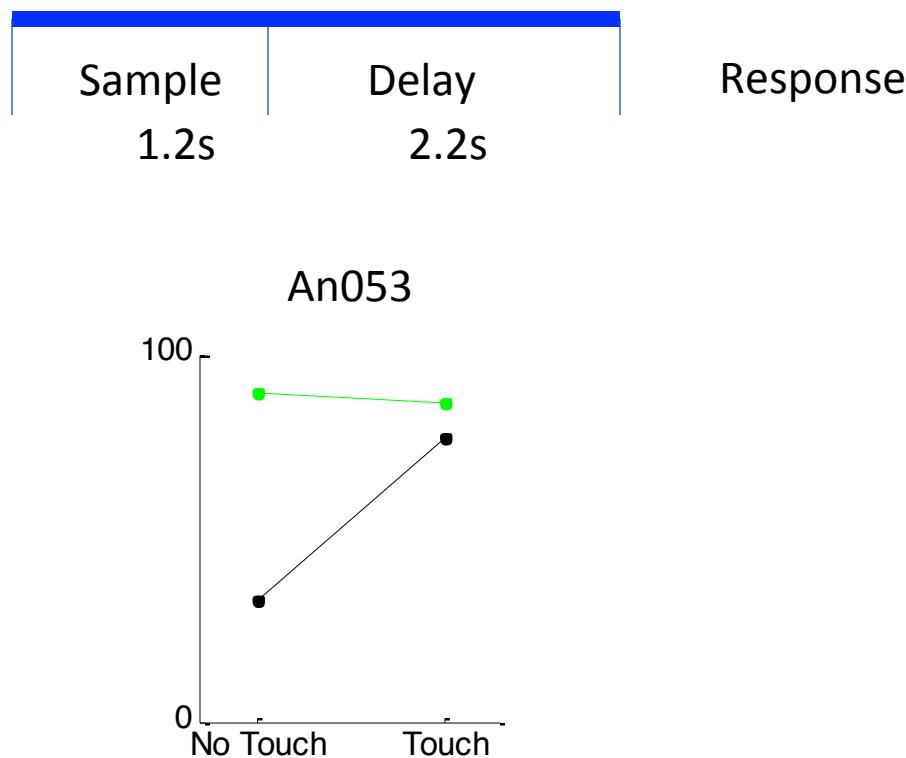


Silencing left vM1 during sample and early delay had little effect

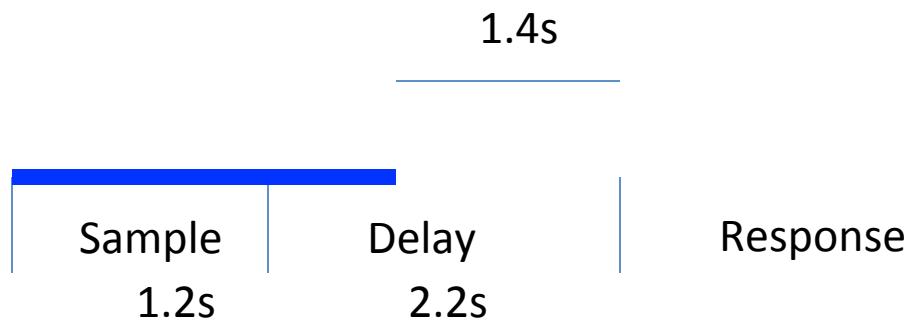


Maybe vM1 is too big to silence completely??

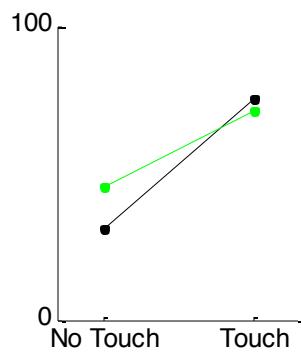
**Scanning laser beam
From 0.8-1.8 AP**



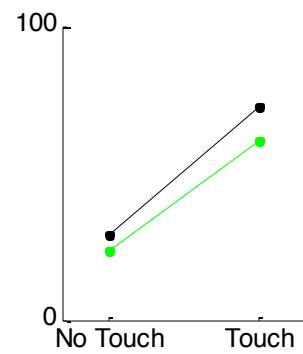
Scanning silencing during sample and early delay



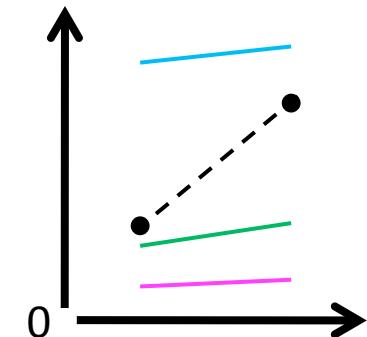
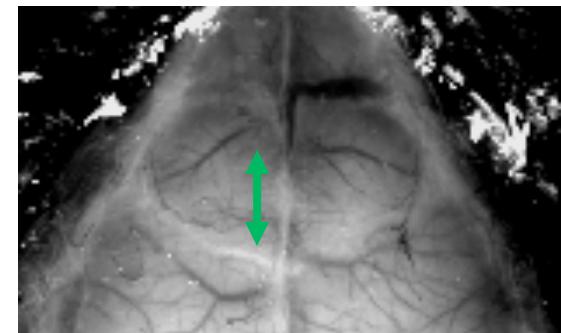
An049



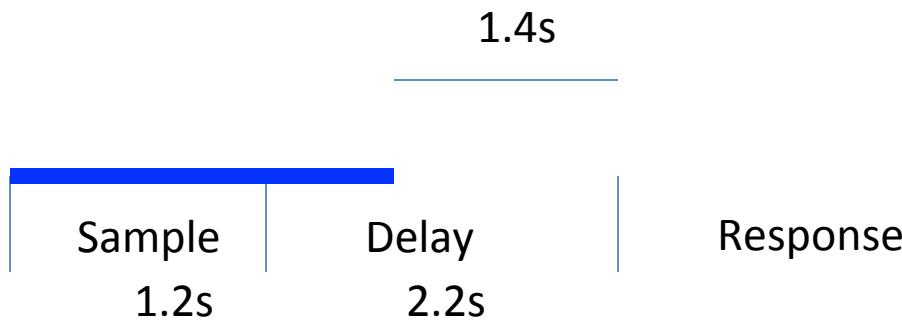
An053



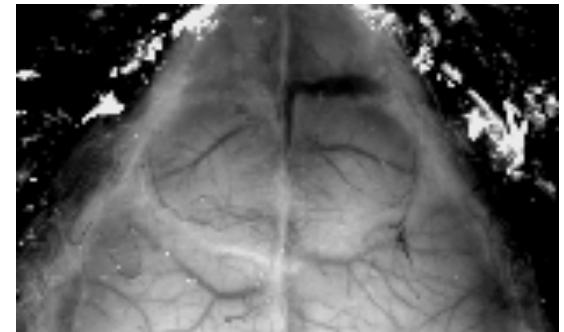
Scanning laser beam
From 0.8-1.8 AP



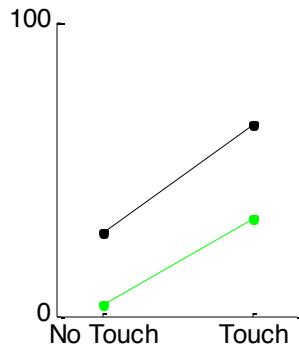
An053 effect not reliable



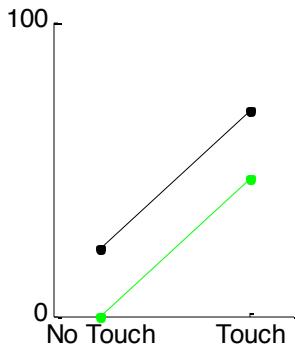
Scanning laser beam
From 0.8-1.8 AP



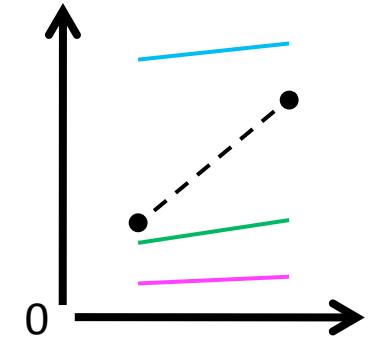
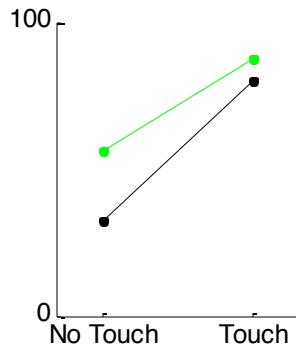
12/8



12/9-10



12/14-15

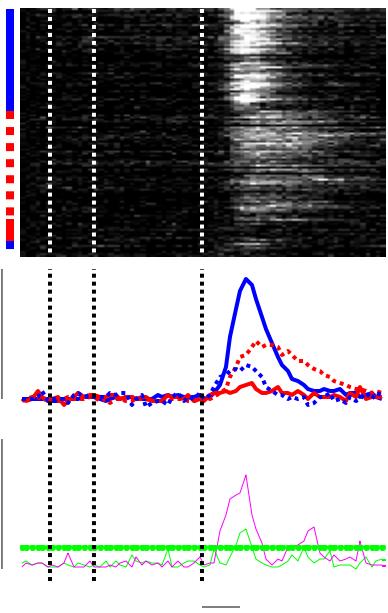


Special Thanks

- ZengCai Guo,
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- Nuo Li
- Simon Peron,
- **Miho Inagaki**

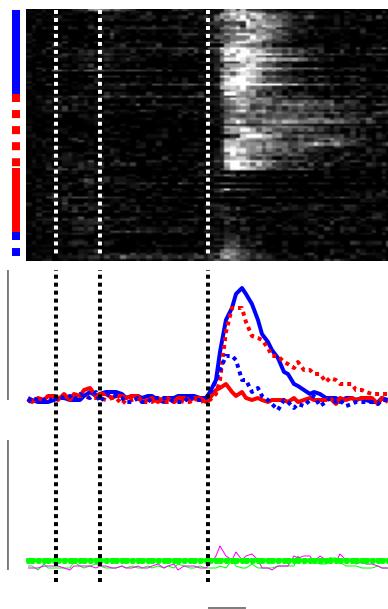
- Karel Svoboda

Complex cell



1831

Water cell?



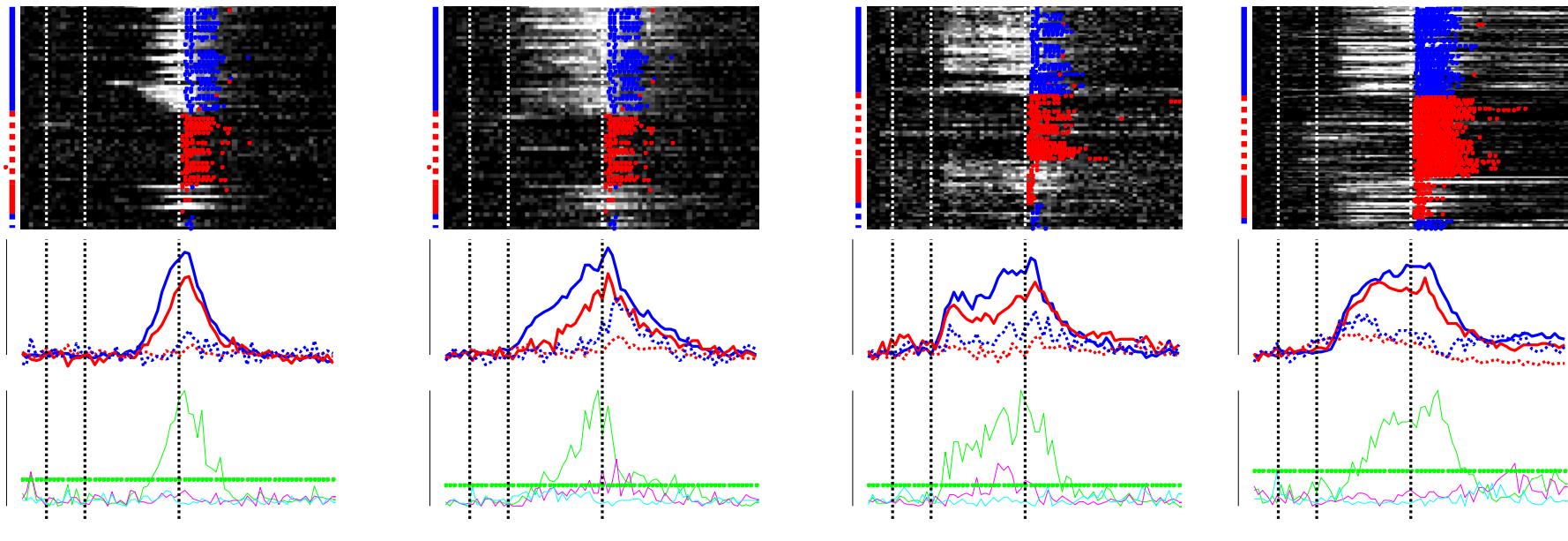
Complex

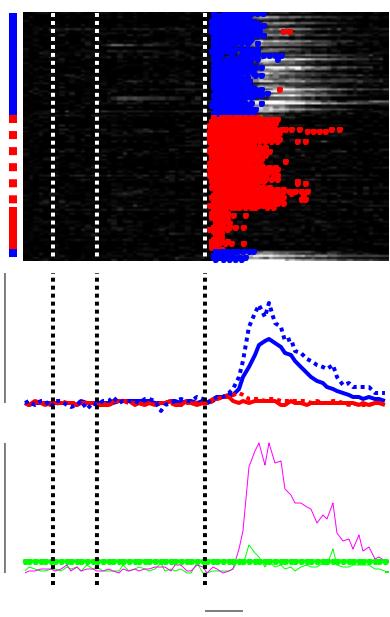
Ramping pole location cells

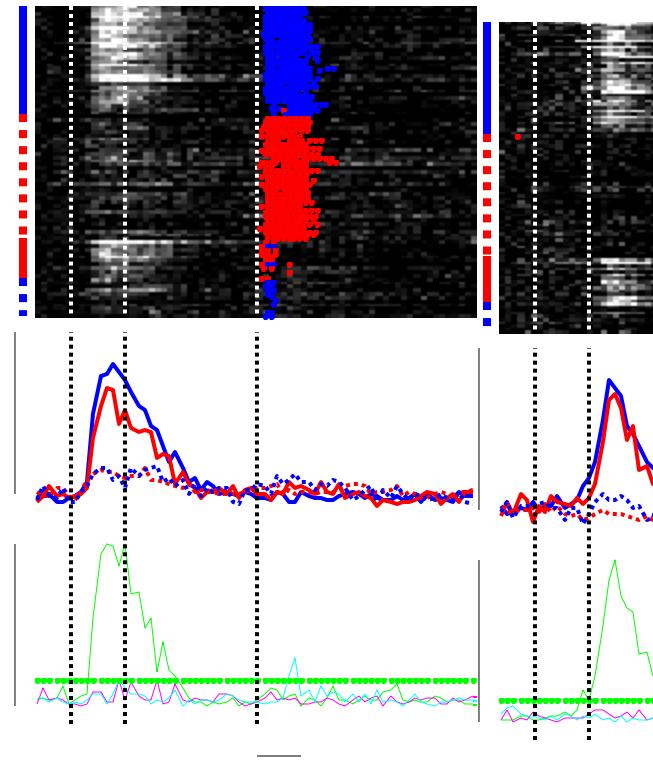
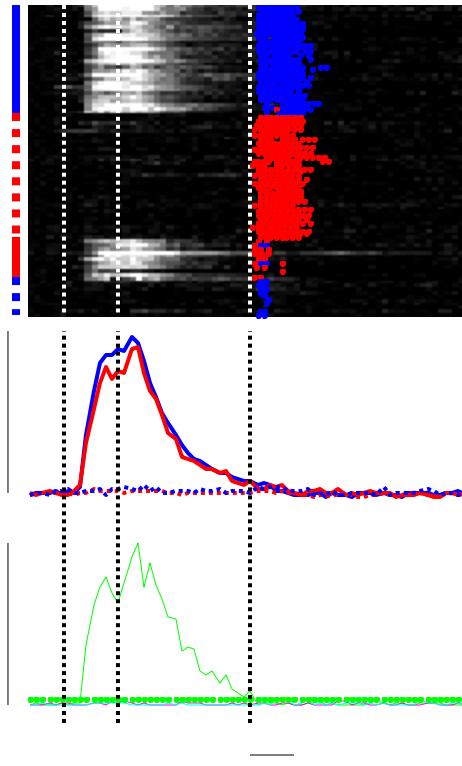
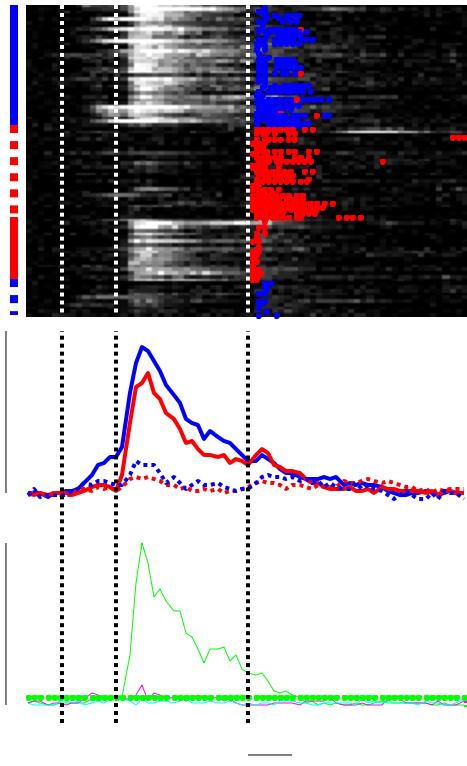
Pole loc
Posterior Anterior

Lick dir

Right ————
Left ————





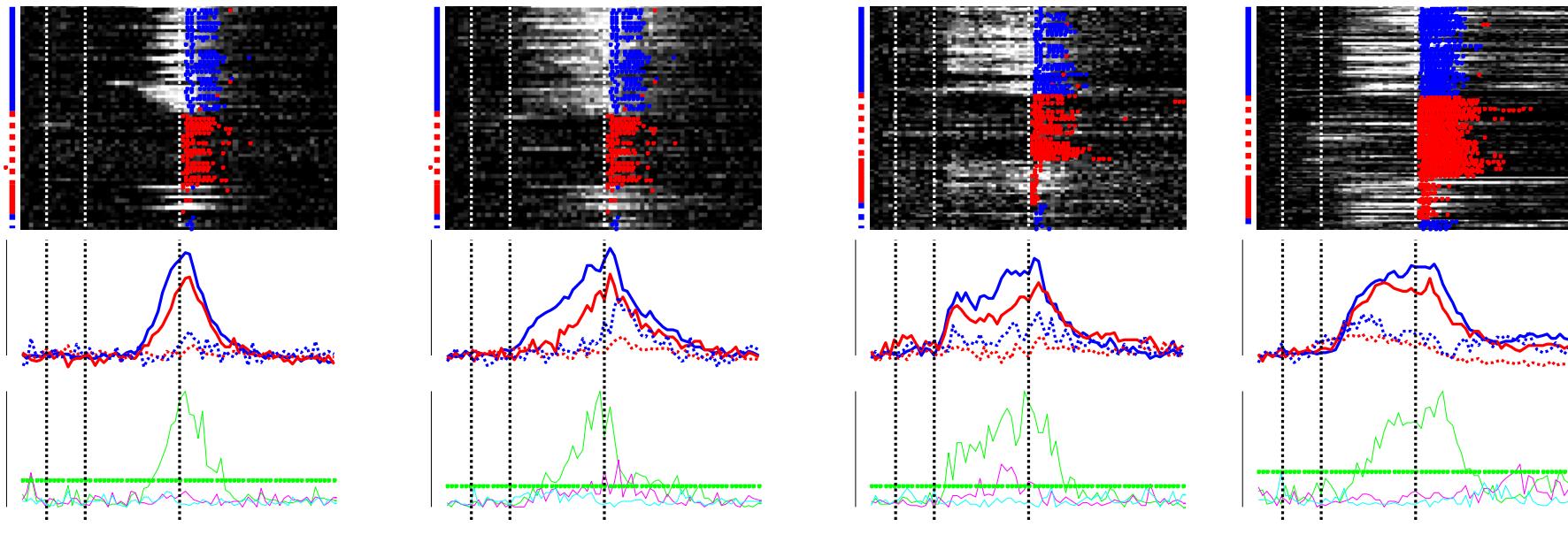


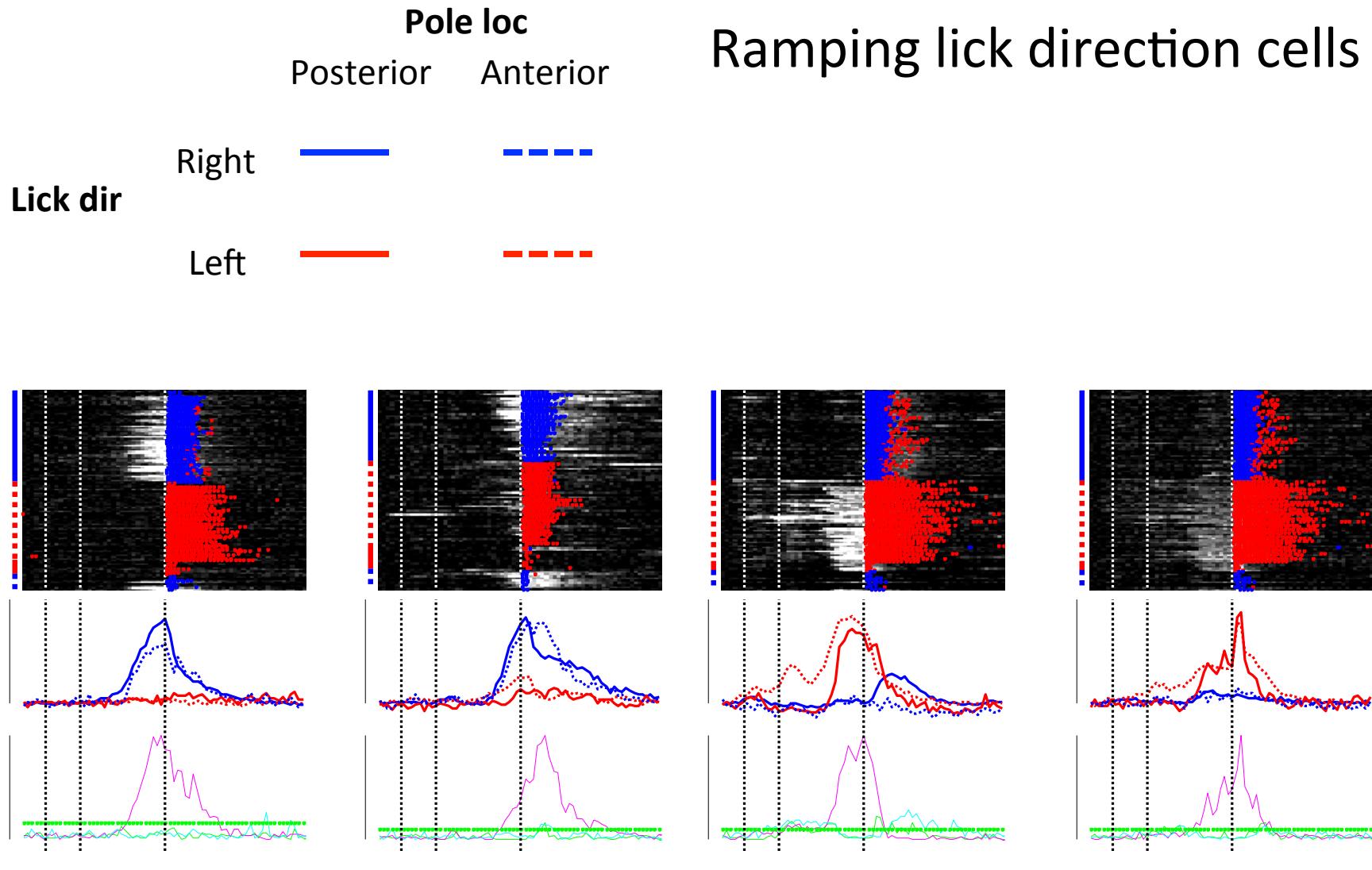
Ramping pole location cells

Pole loc
Posterior Anterior

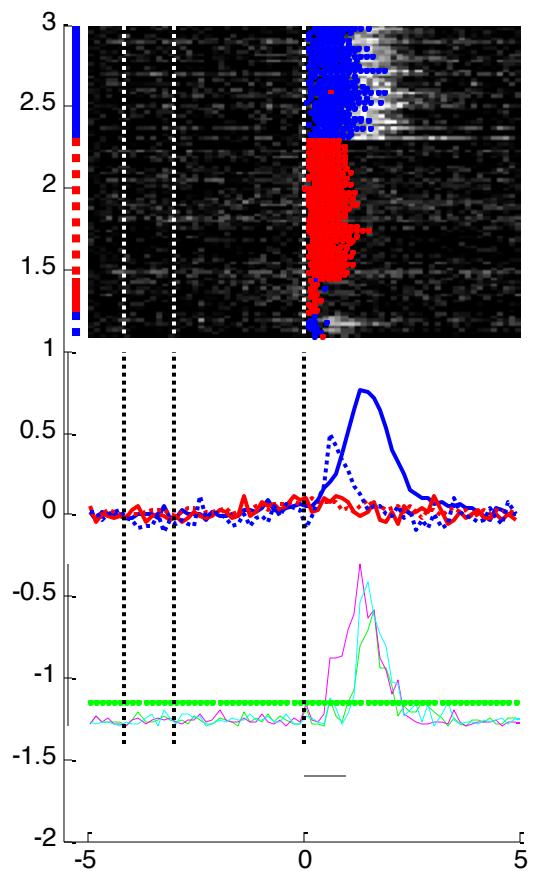
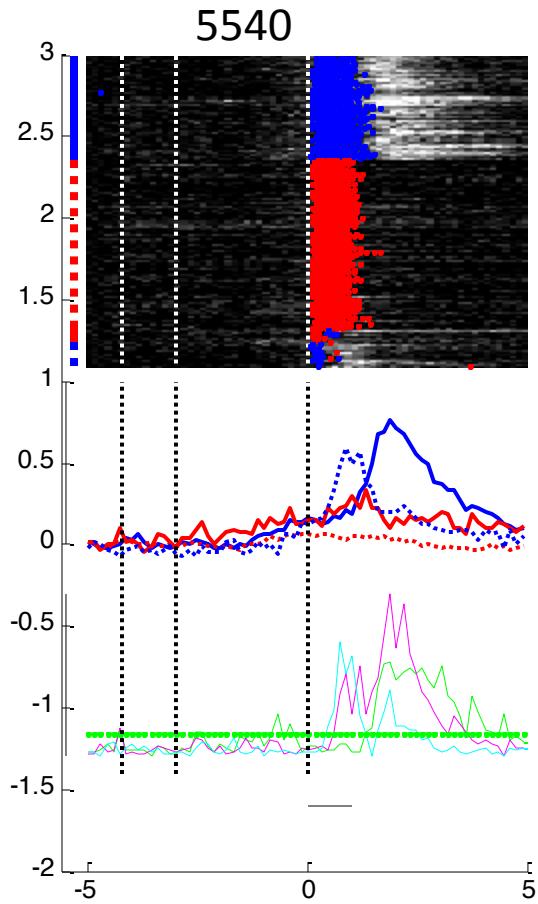
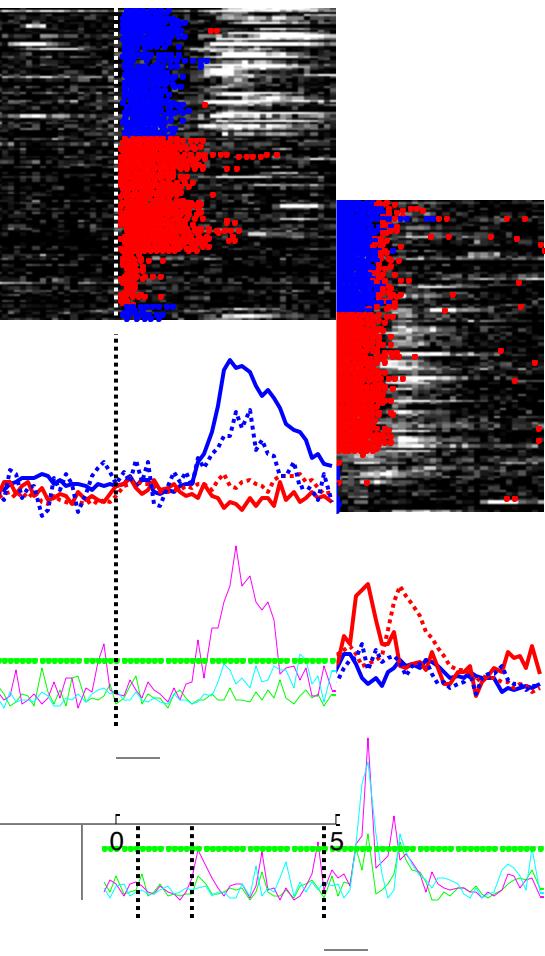
Lick dir

Right ————
Left ————



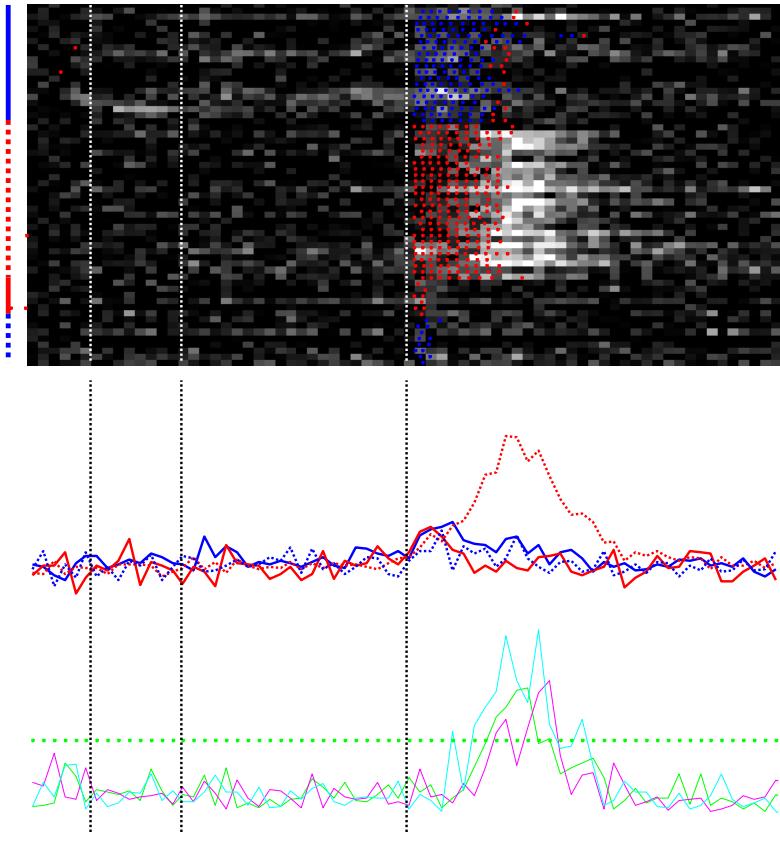


Stop licking



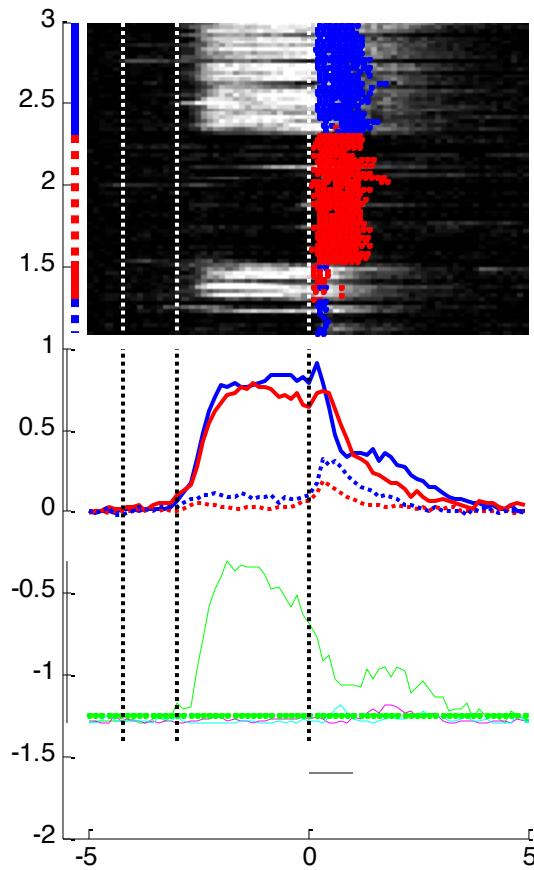
An043_20140911_AL_240_pwr35_cell10

Left water



An043_20140911_ALM_300um_cell14

sensory



cell2173

Sensory motor

