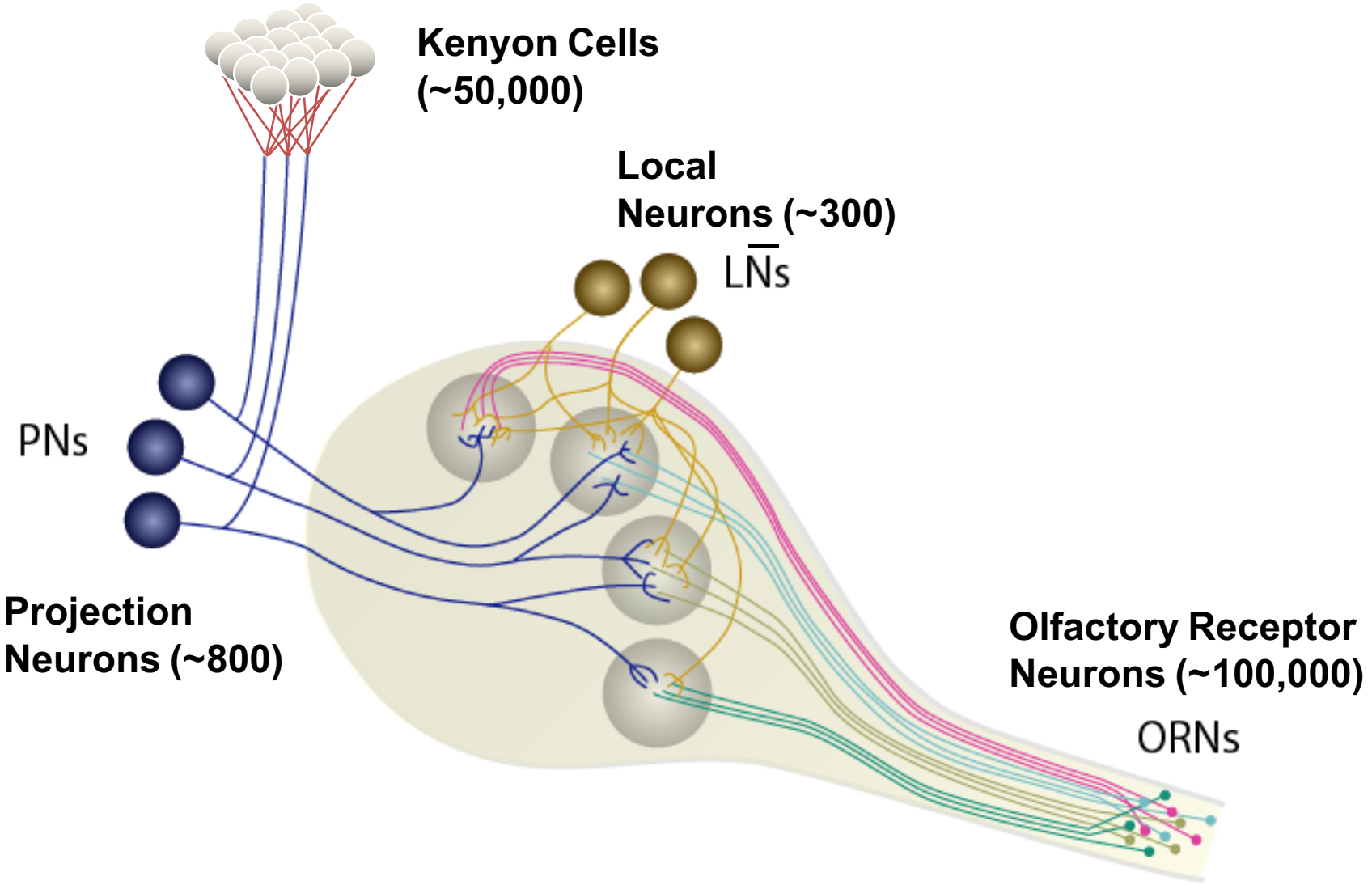
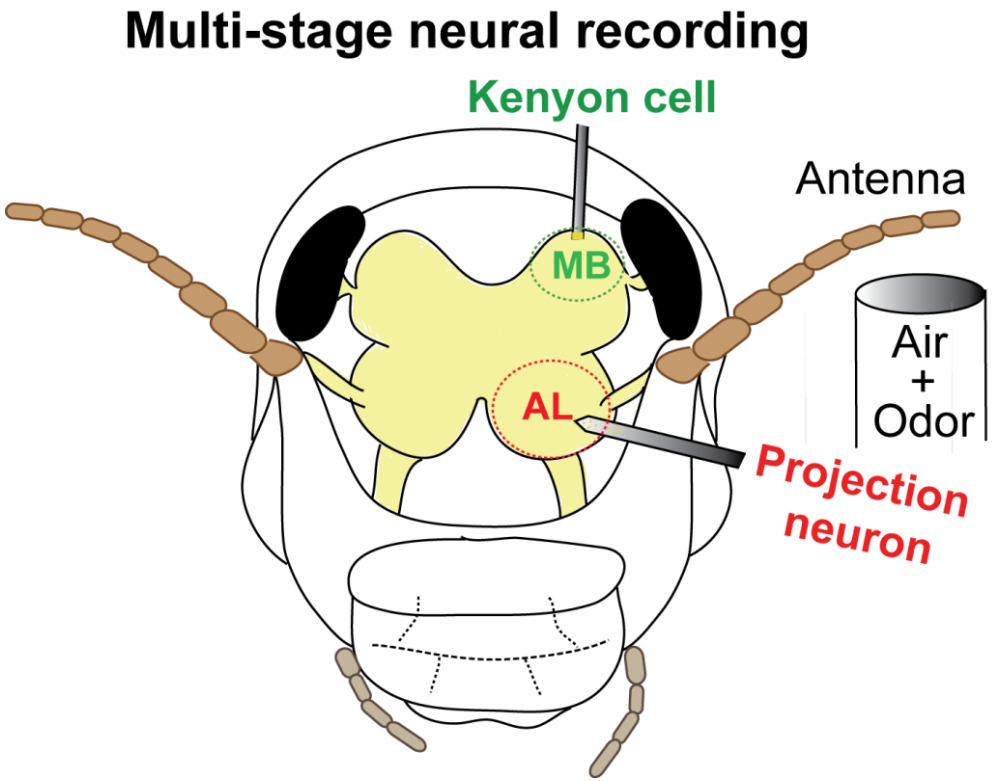
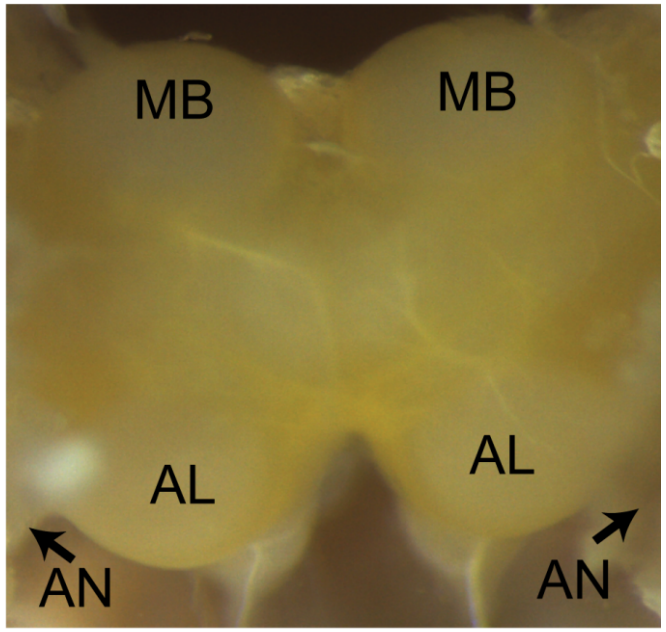
How does a simple neural circuit generate orthogonal ON and OFF responses to the same stimulus?

Insect Olfactory System



Neural Recordings from Different Brain Centers

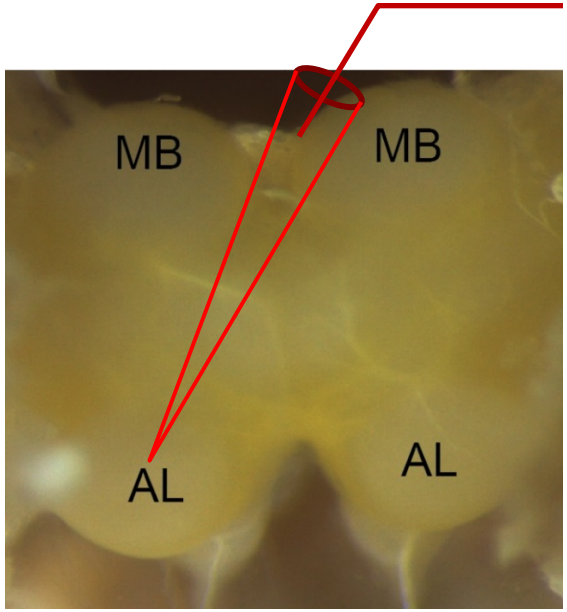




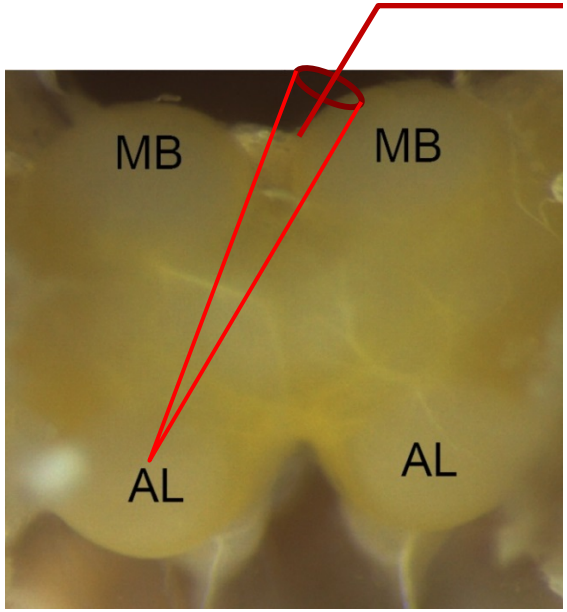
Laurent and Davidowitz, 1994

Stopfer and Laurent, 1999

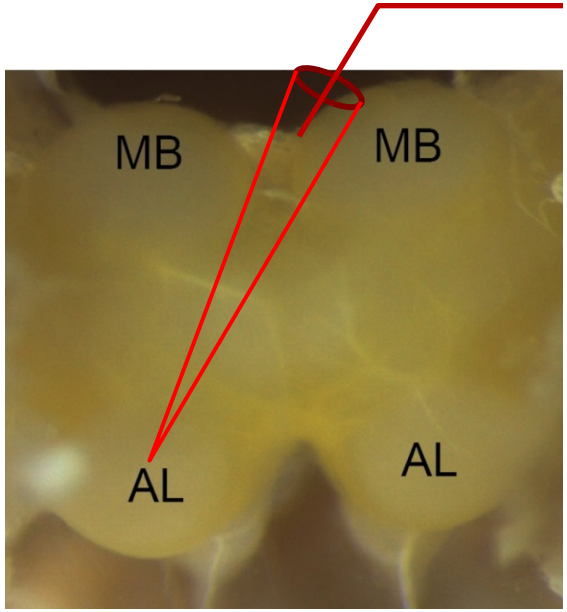
Projection Neuron (PN) Responses

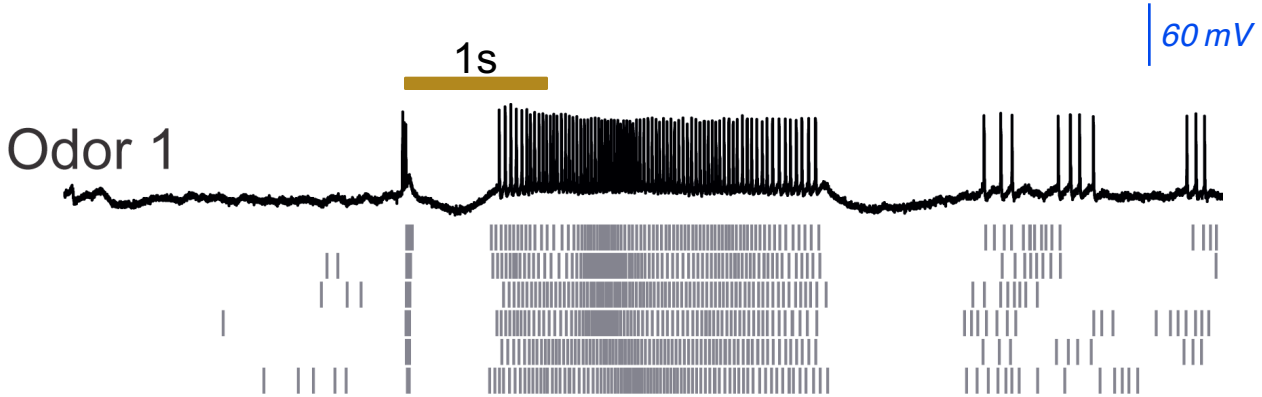


Projection Neuron (PN) Responses

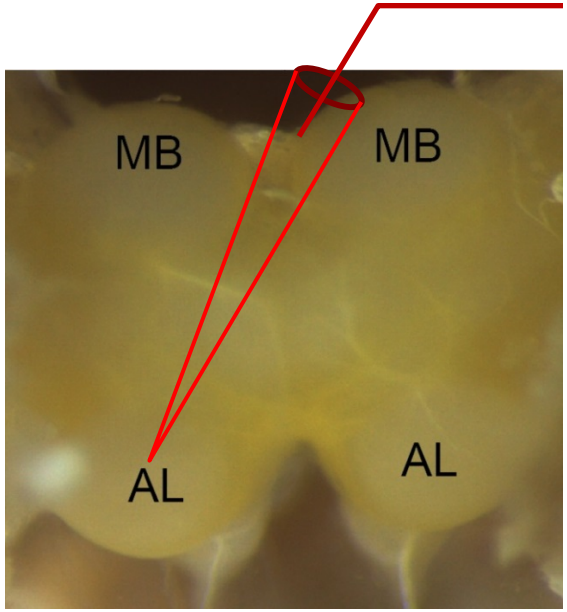


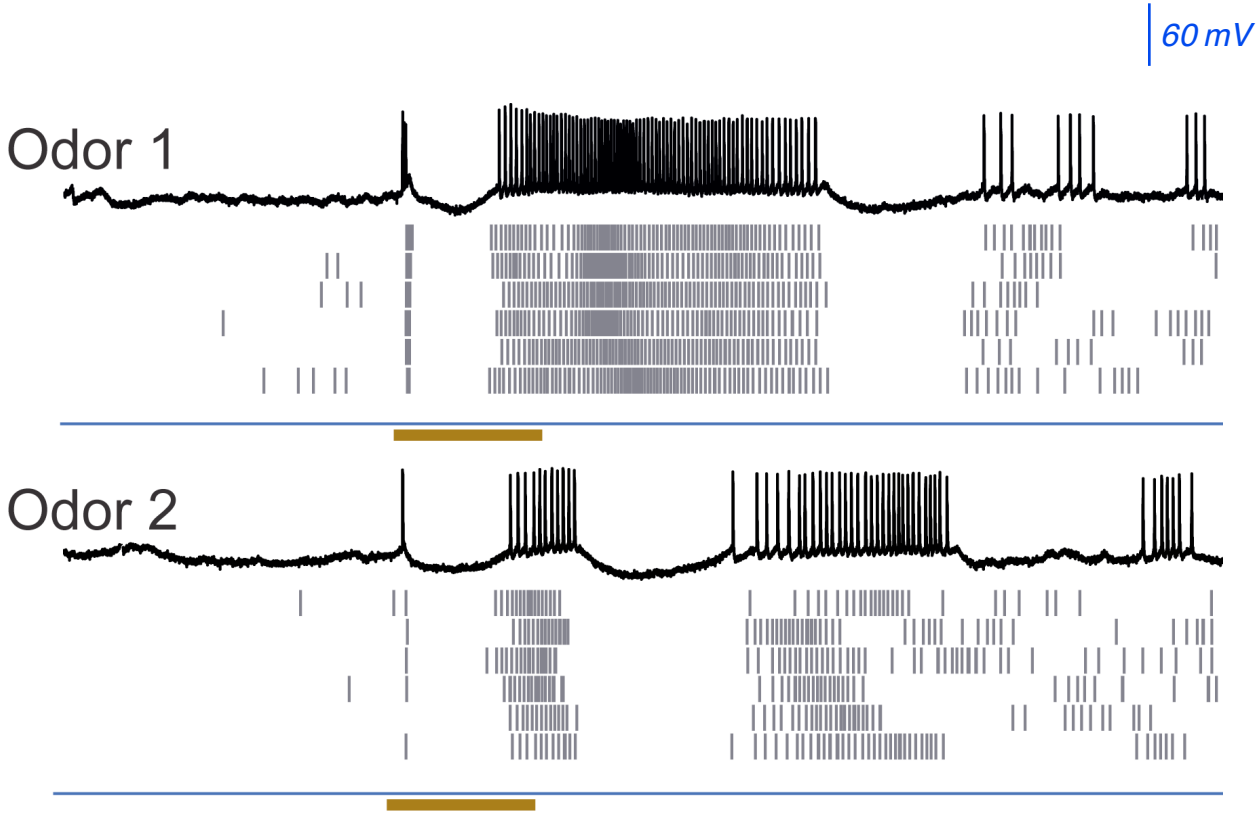
Projection Neuron (PN) Responses





Projection Neuron (PN) Responses to Different Odors



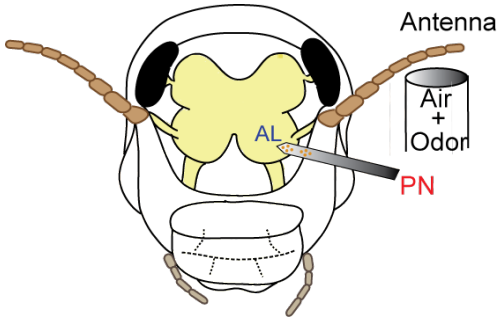


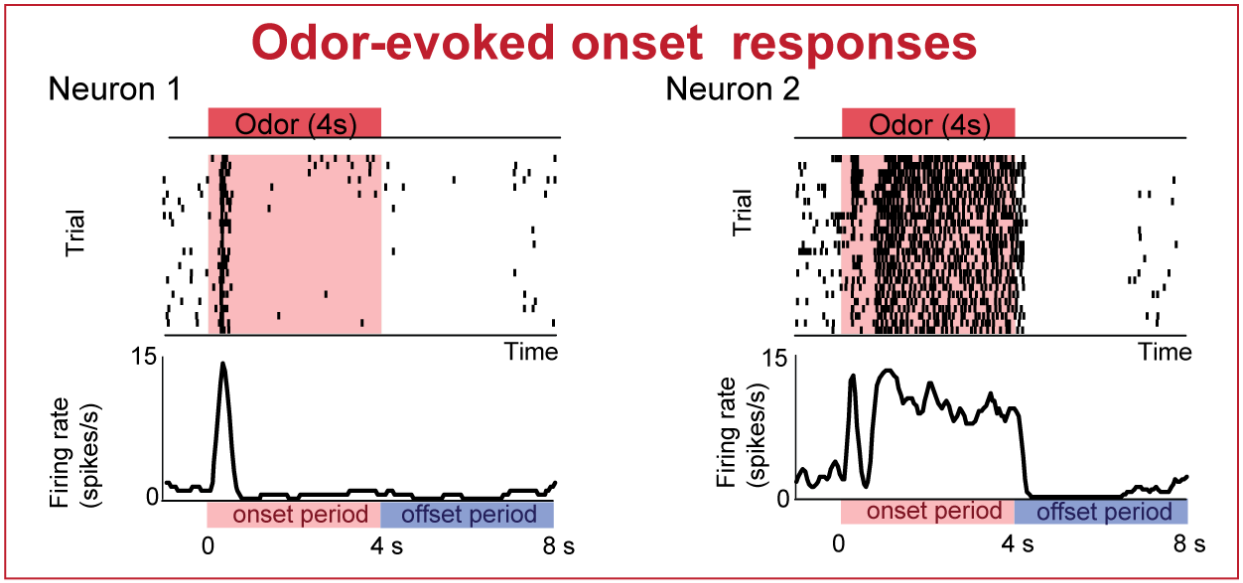
Same projection neuron can respond to different odors with different response profiles

Raman et al. 2010

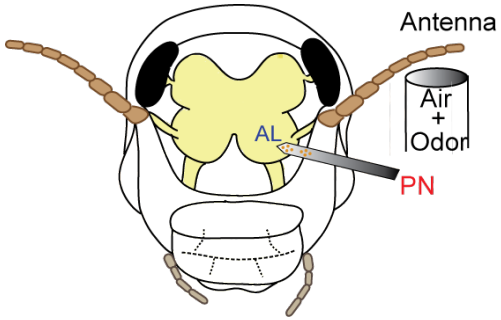
What are ON and OFF responses?

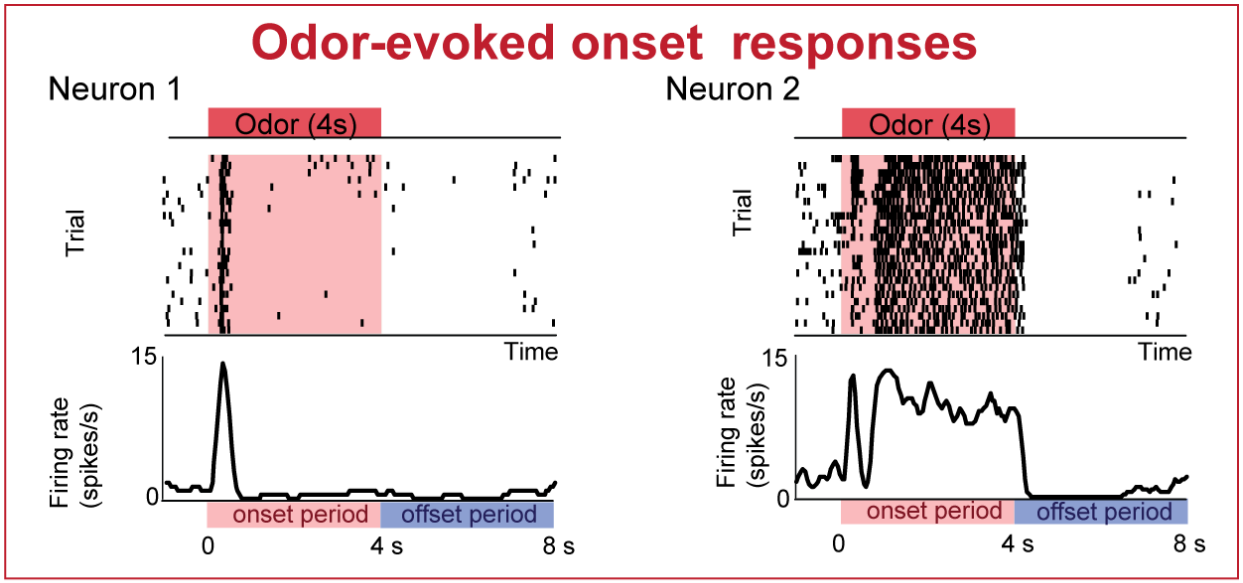
Onset vs. Offset Neural Response

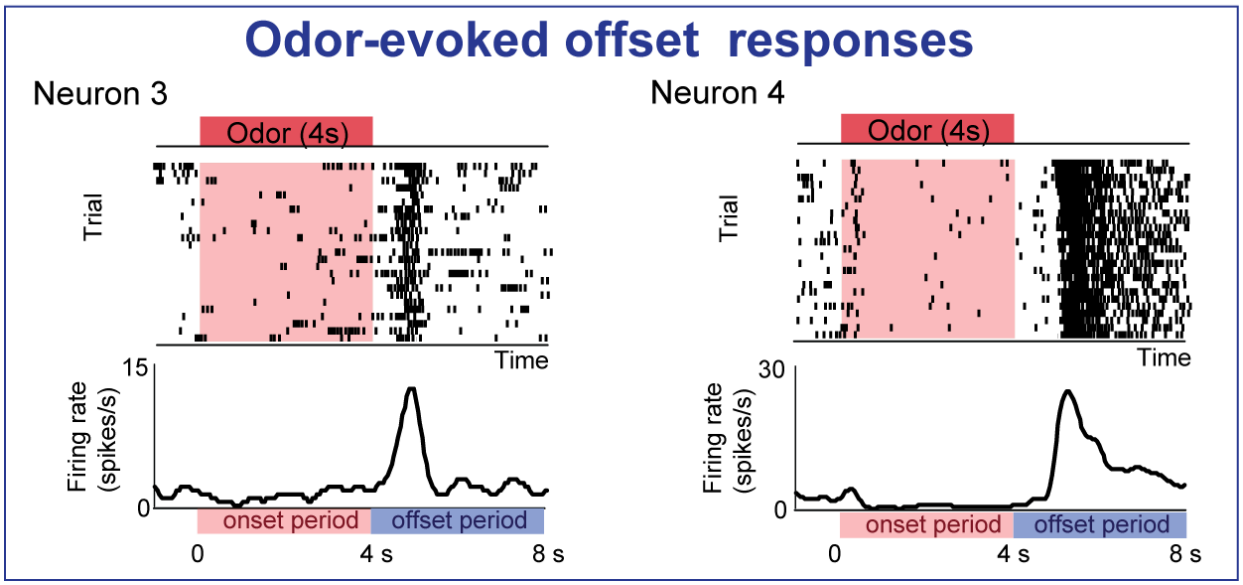




Onset vs. Offset Neural Response

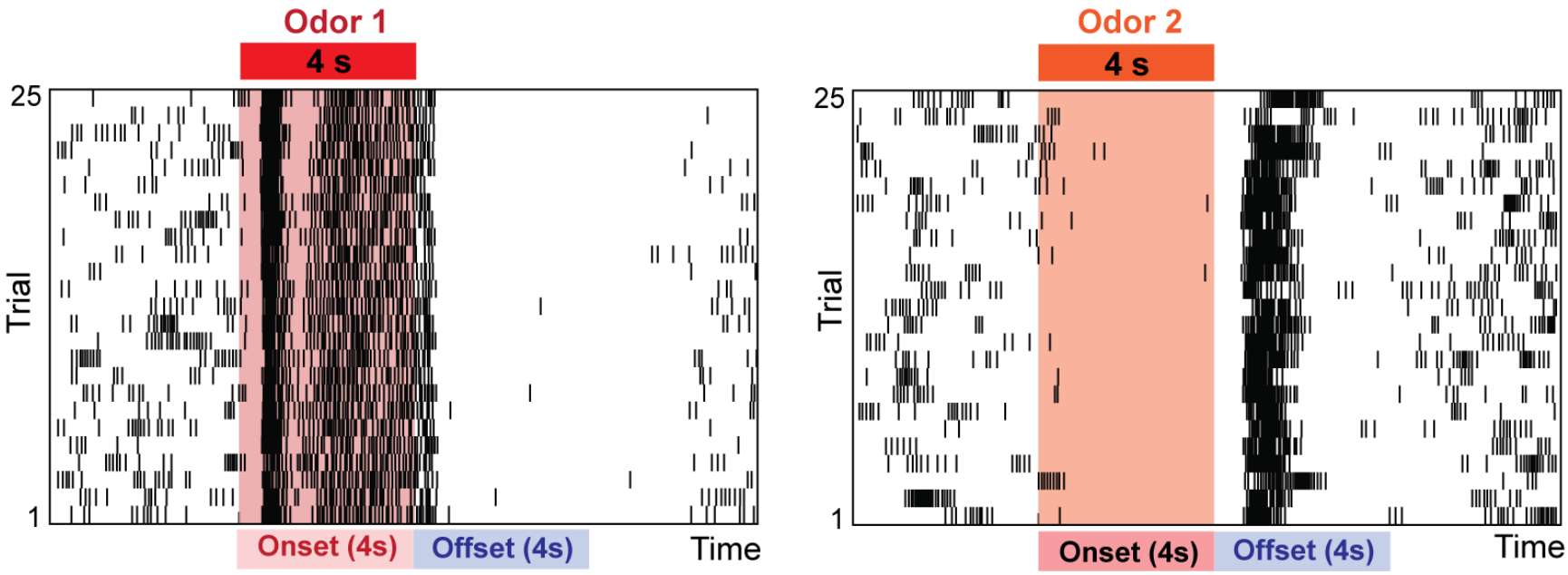




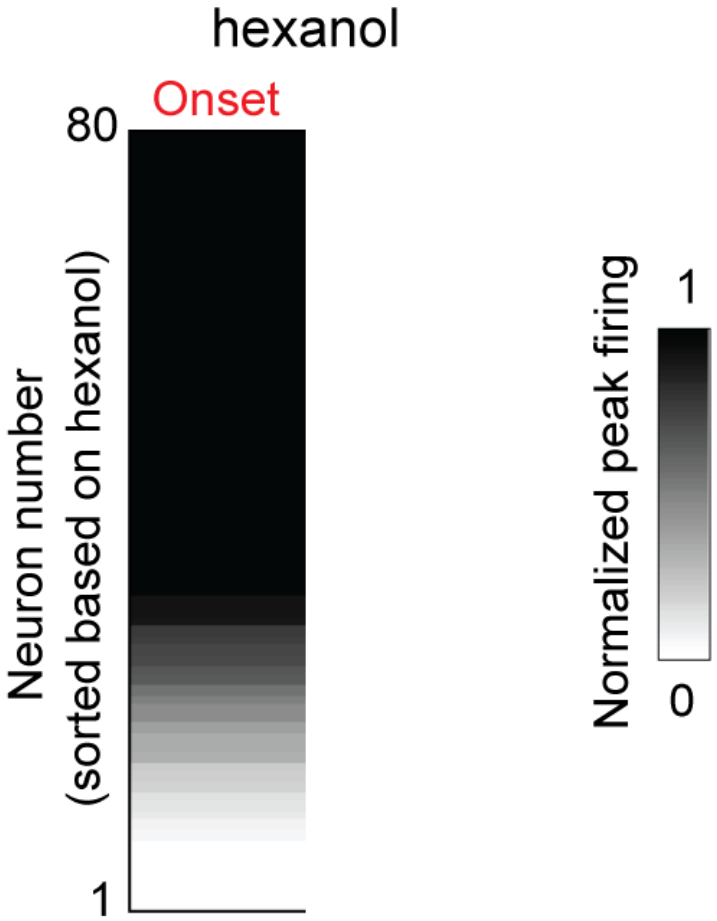


Onset and Offset Neural Responses Are Odor Dependent

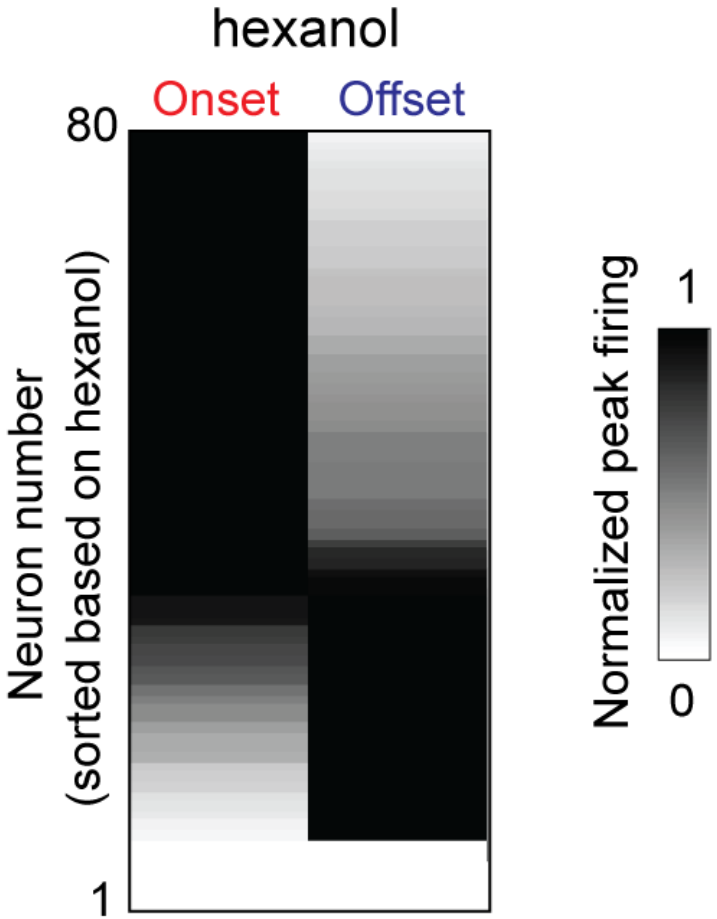
Same neuron can respond to different odors either during the onset or offset



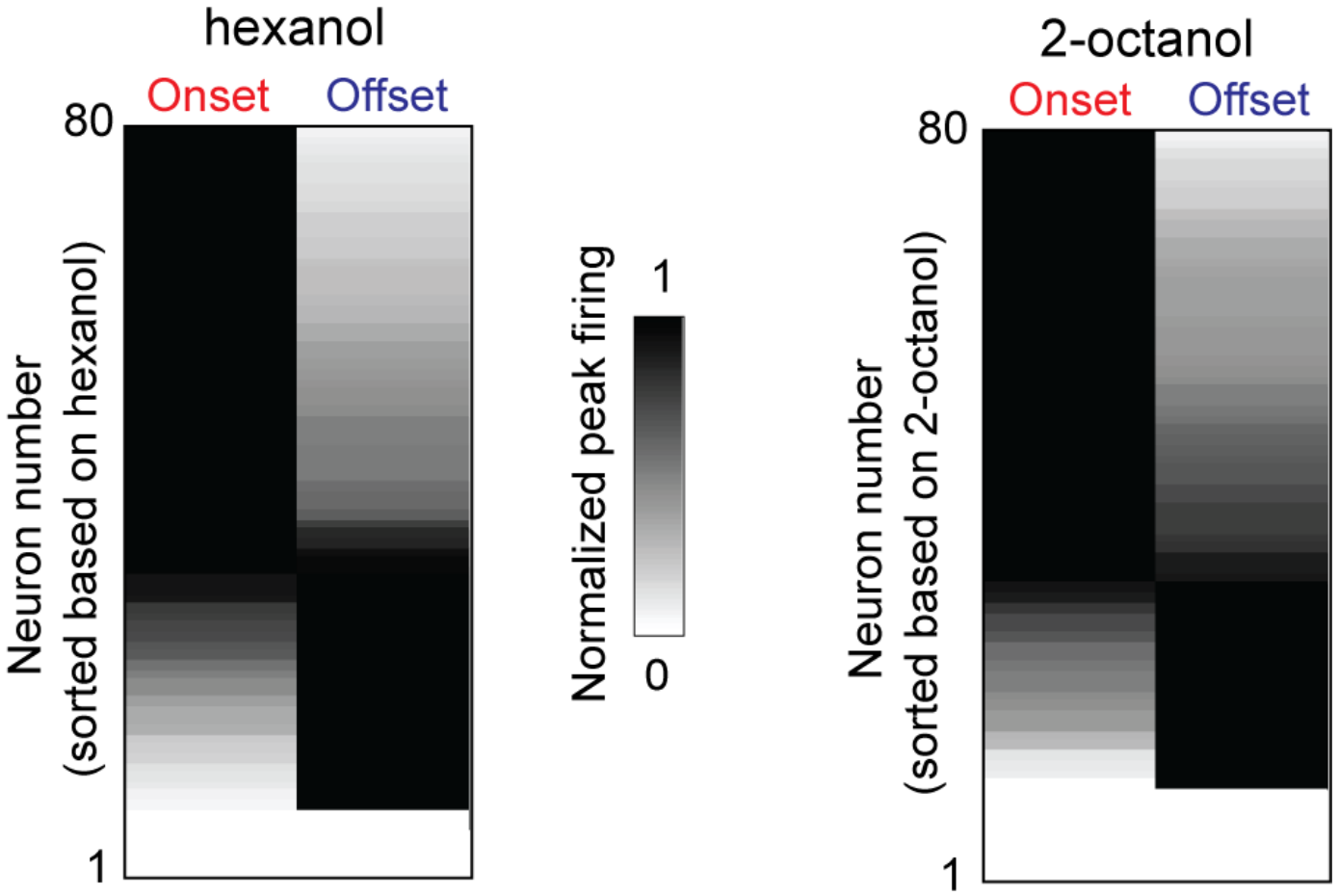
Onset and Offset Neural Population Sets Are Flexible and Minimally Overlapping

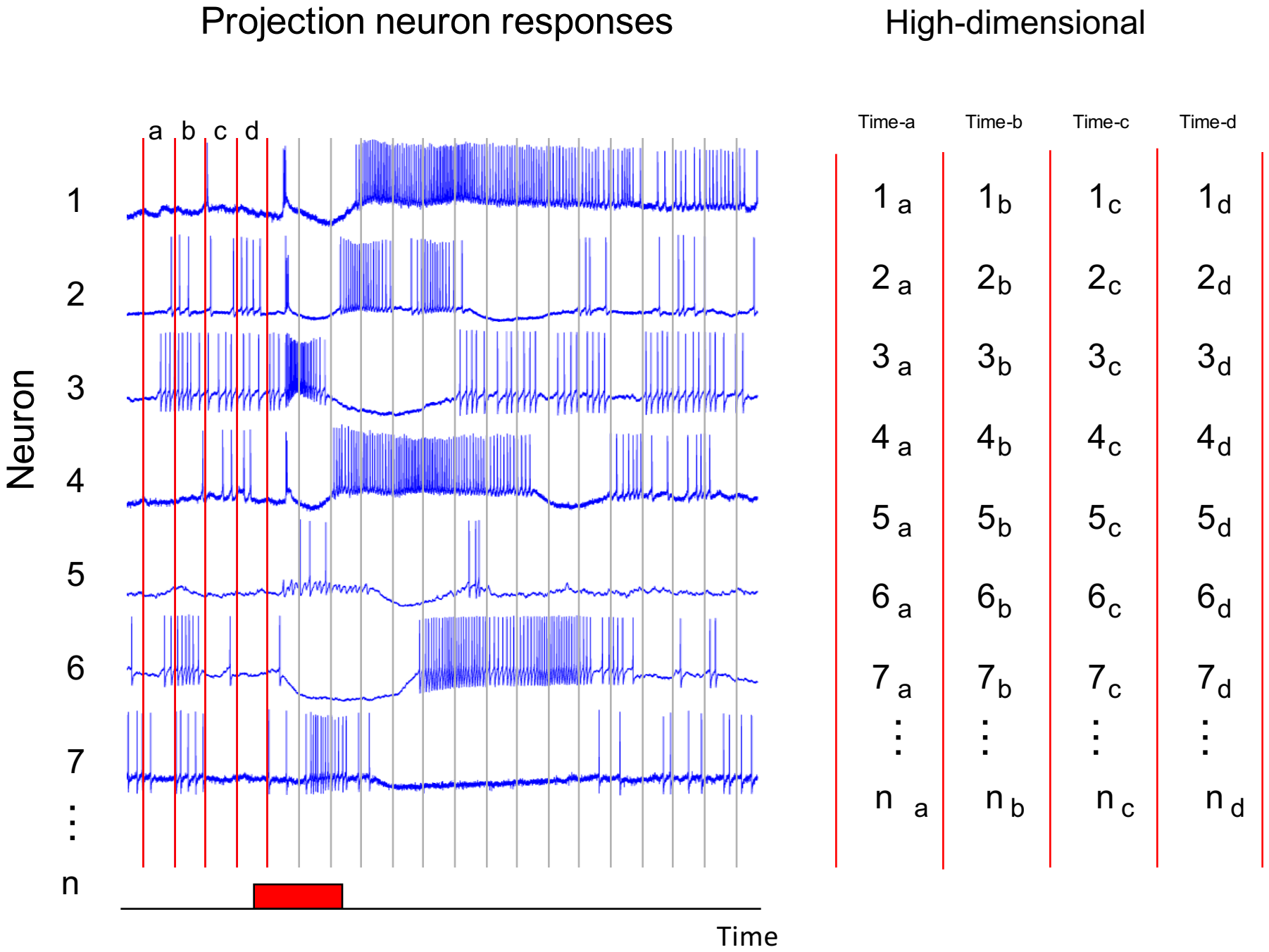


Onset and Offset Neural Population Sets Are Flexible and Minimally Overlapping

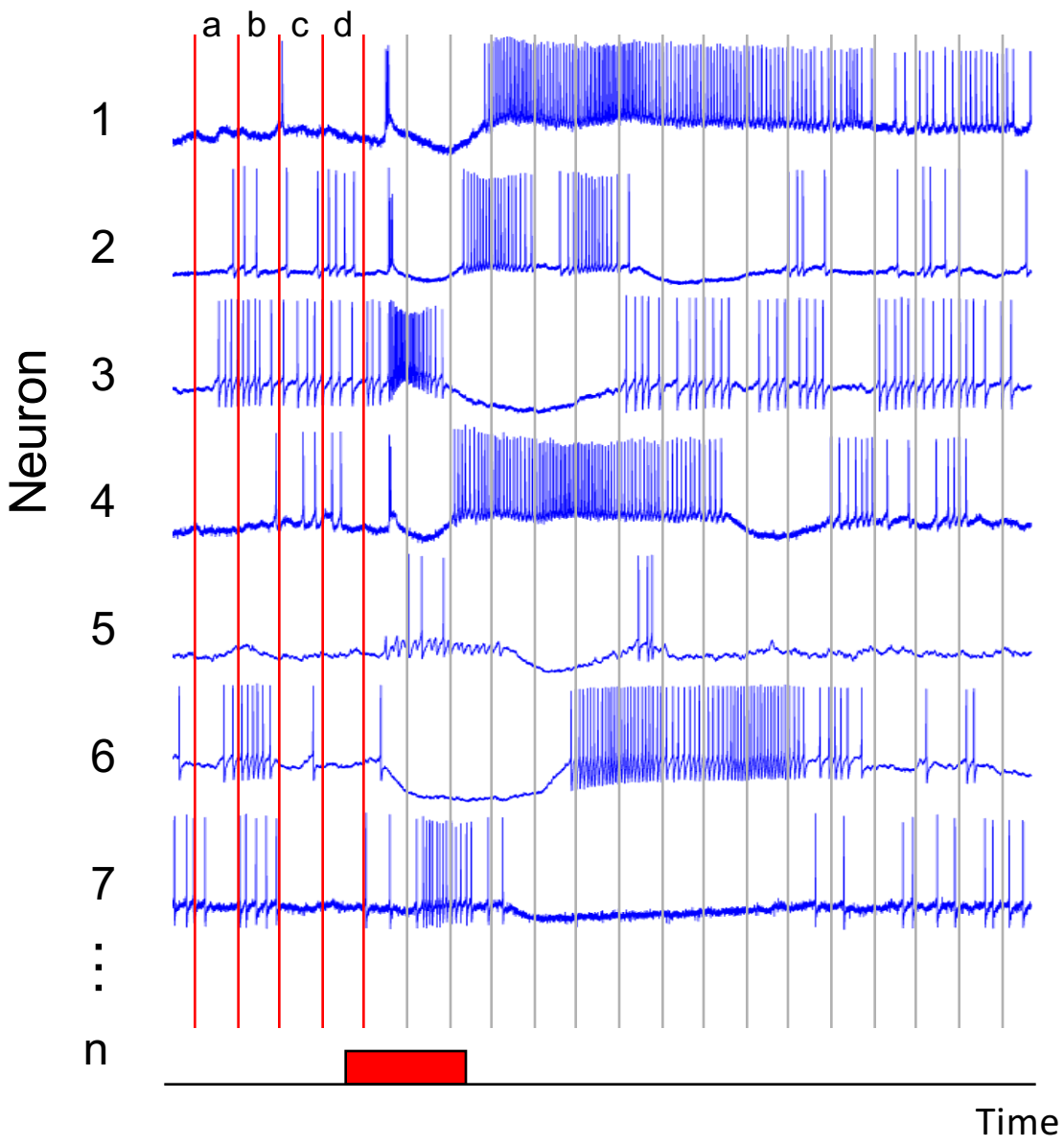


Onset and Offset Neural Population Sets Are Flexible and Minimally Overlapping




Projection neuron responses
High-dimensional
a b c d
Neuron
1
2
3
4
5
6
7
n
Time
Time-a
Time-b
Time-c
Time-d
1 a
1 b
1 c
1 d
2 a
2 b
2 c
2 d
3 a
3 b
3 c
3 d
4 a
4 b
4 c
4 d
5 a
5 b
5 c
5 d
6 a
6 b
6 c
6 d
7 a
7 b
7 c
7 d
n a
n b
n c
n d

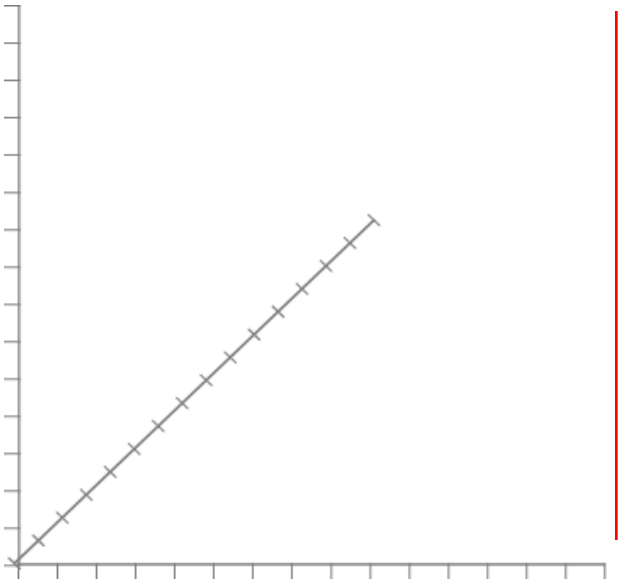
Projection neuron responses

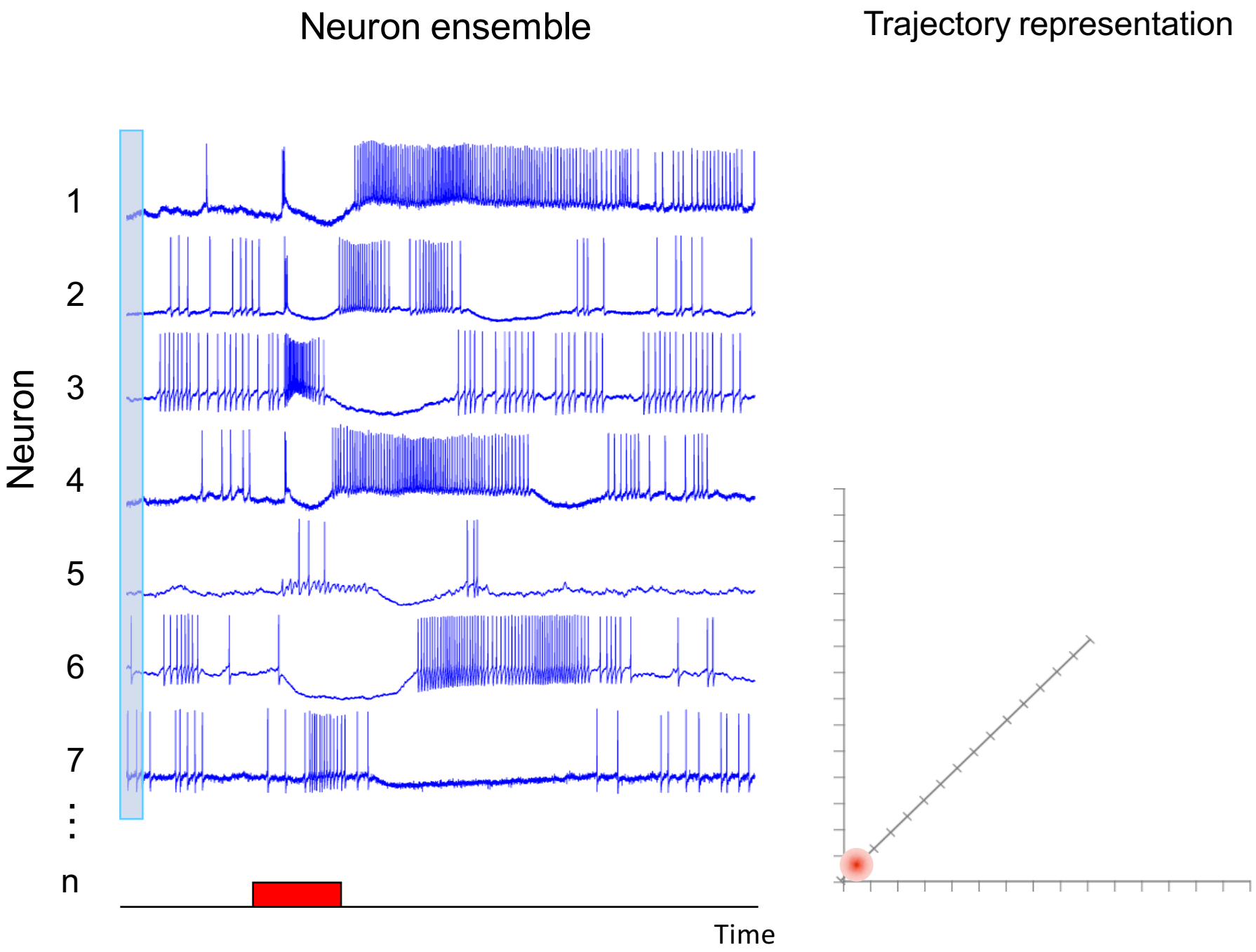


Dimensionality reduction

Time-a	Time-b	Time-c	Time-d
1_a	1_b	1_c	1_d
2_a	2_b	2_c	2_d
3_a	3_b	3_c	3_d

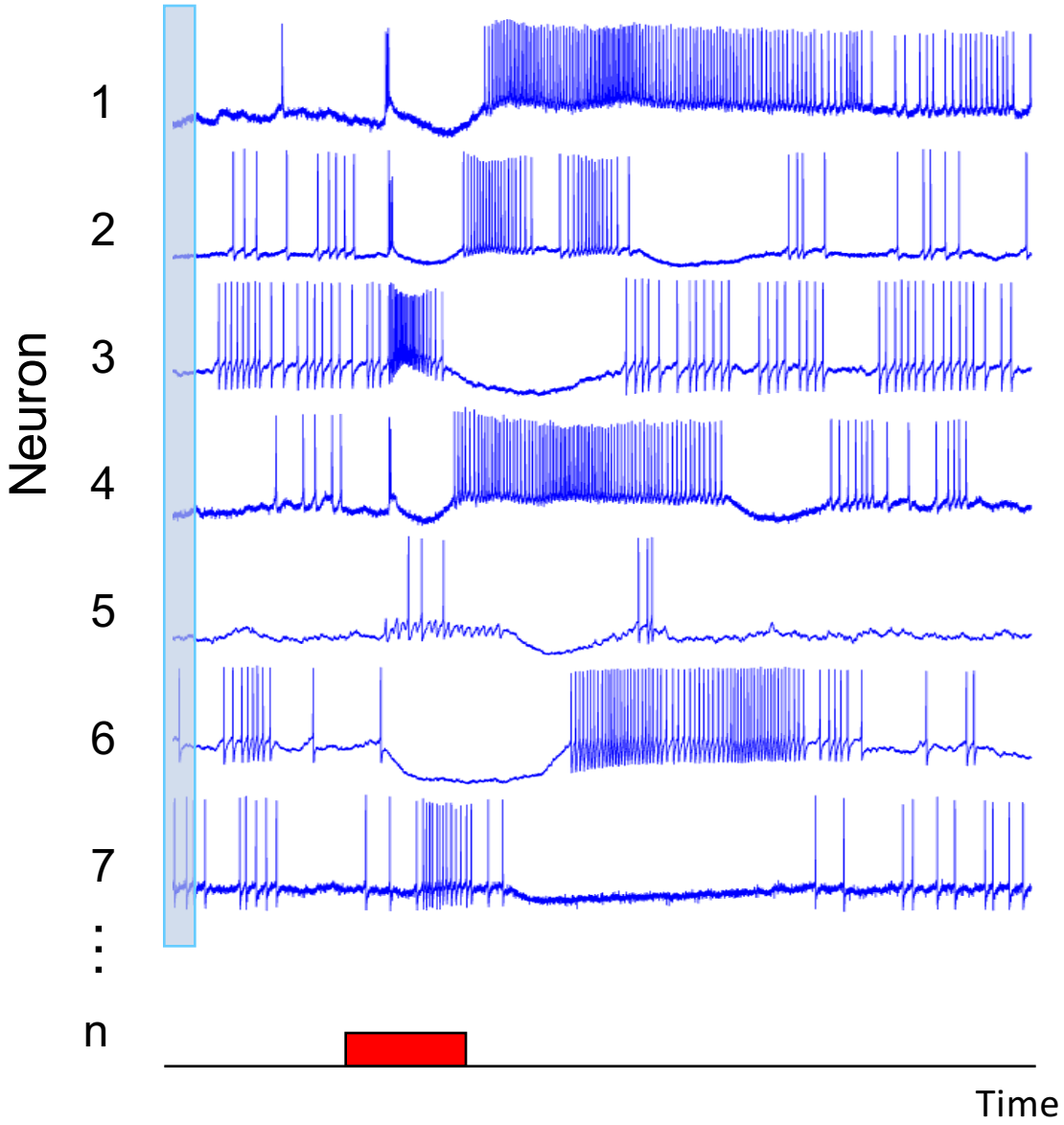
Non-linear – Locally Linear Embedding (LLE)
Linear – Principal Component Analysis (PCA)

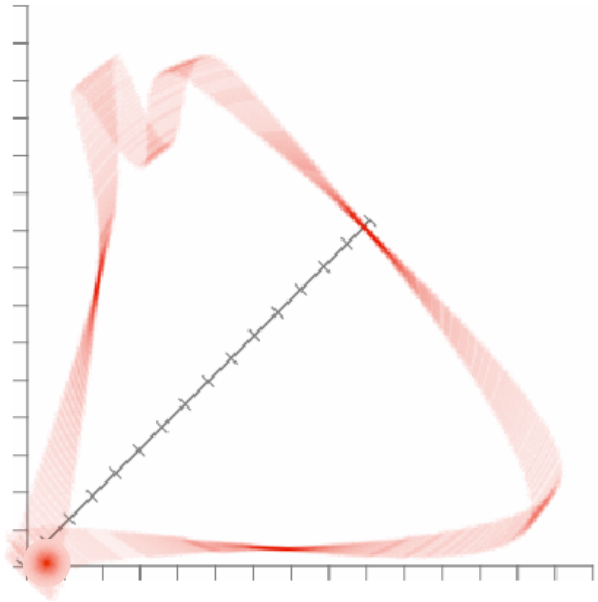



Neuron ensemble
Trajectory representation
Neuron
1
2
3
4
5
6
7
⋮
n
Time

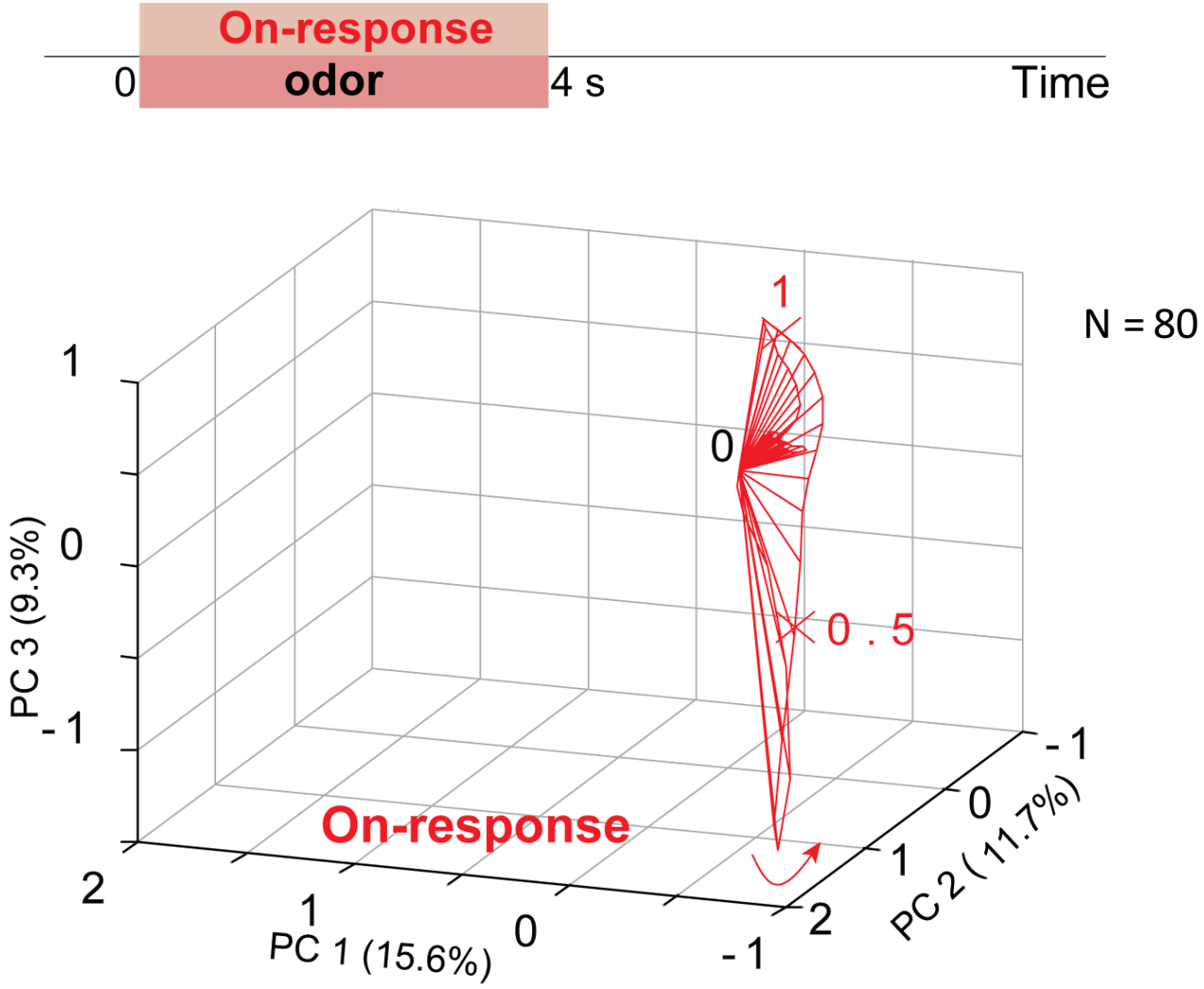
Neuron ensemble

Trajectory representation

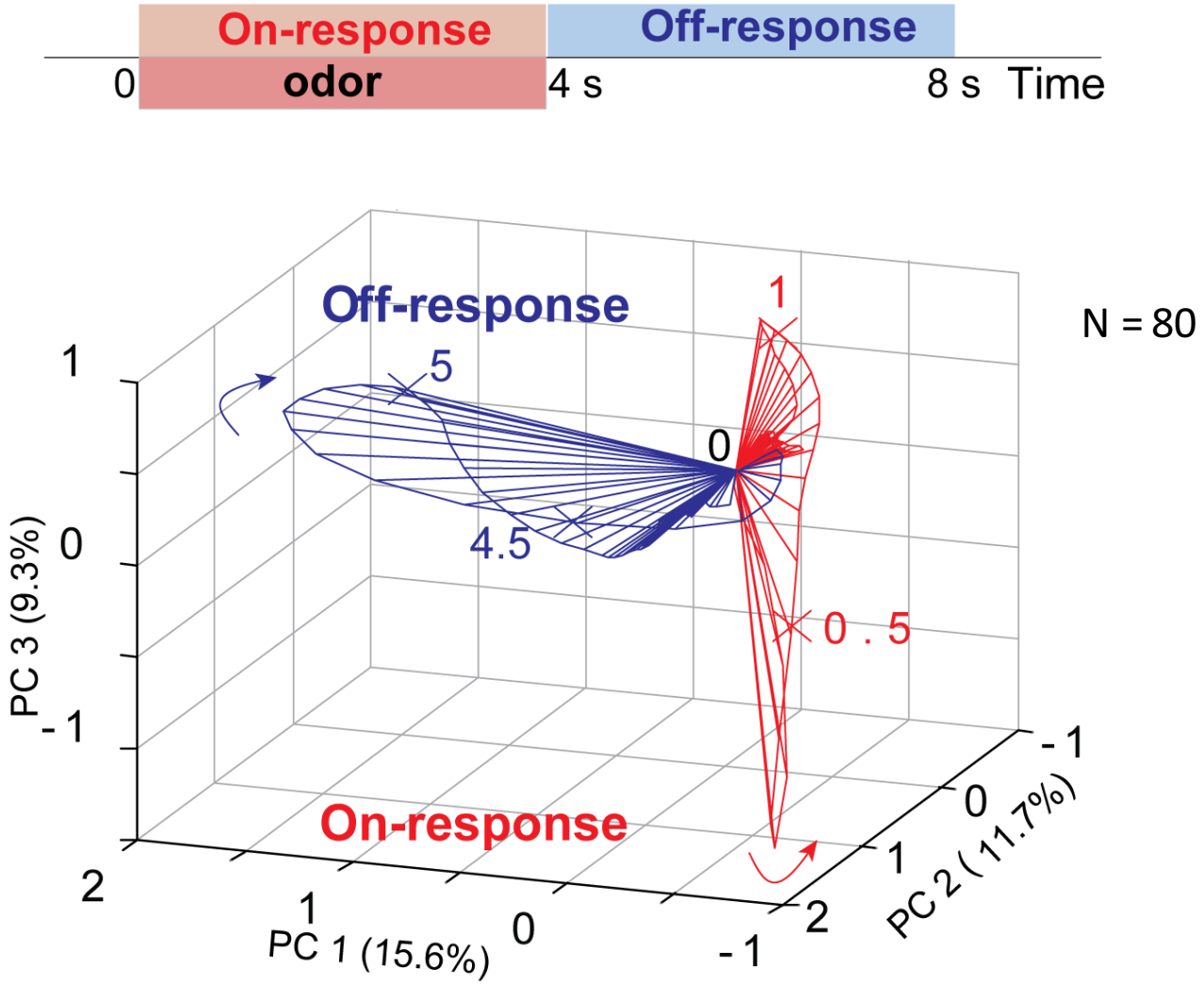




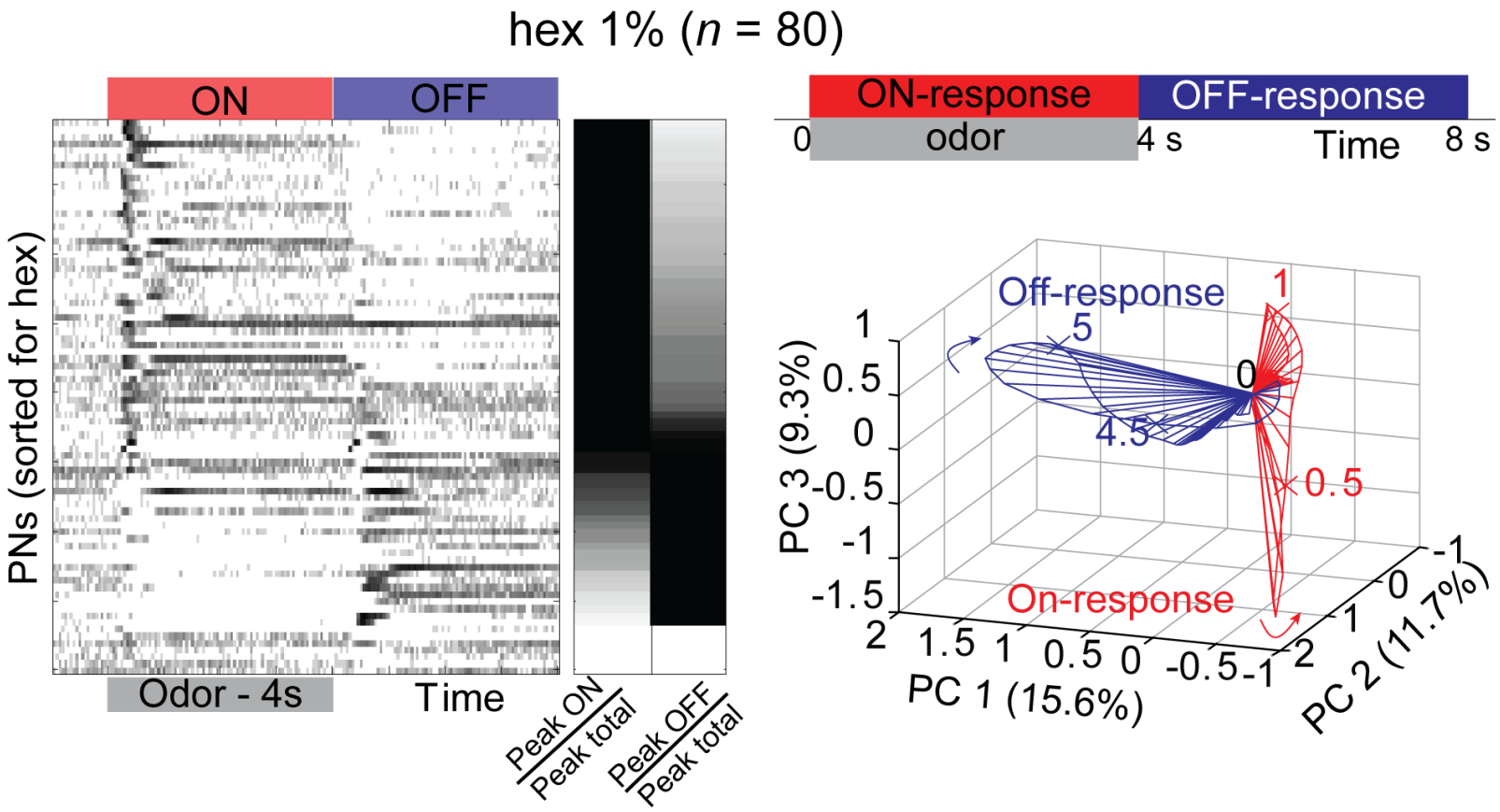
Onset and Offset Population Neural Responses Are Orthogonal



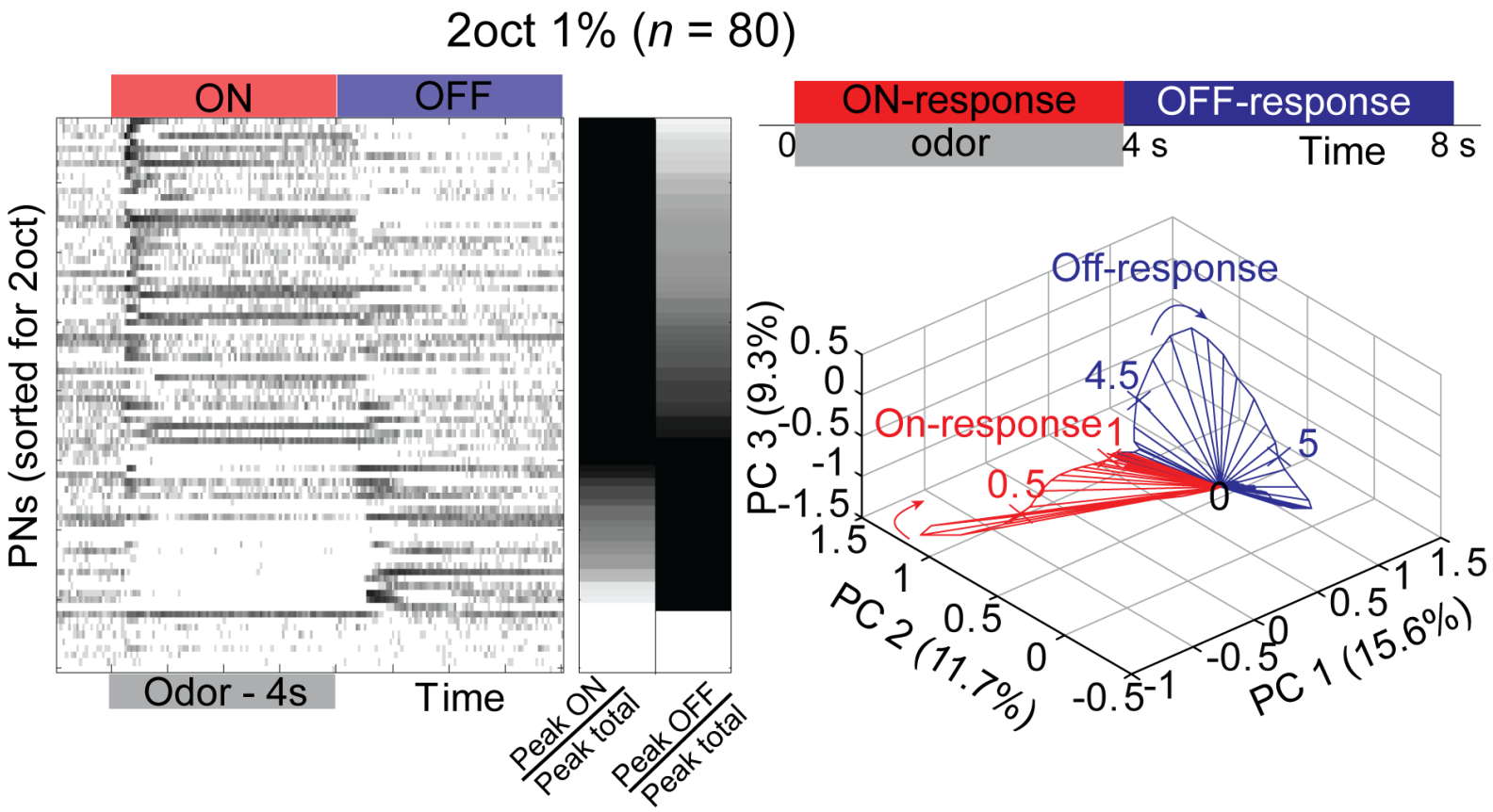
Onset and Offset Population Neural Responses Are Orthogonal



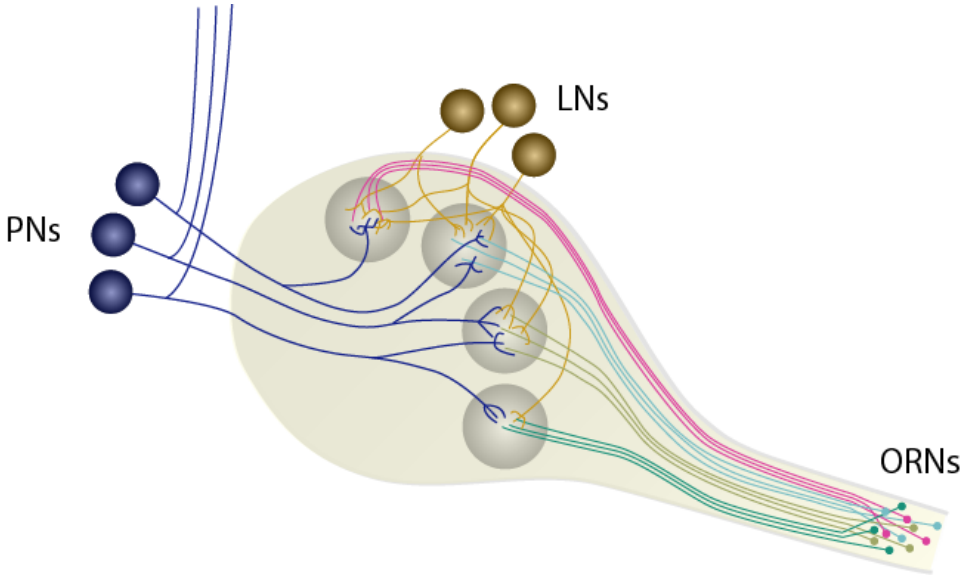
Onset and Offset Population Neural Responses Are Orthogonal

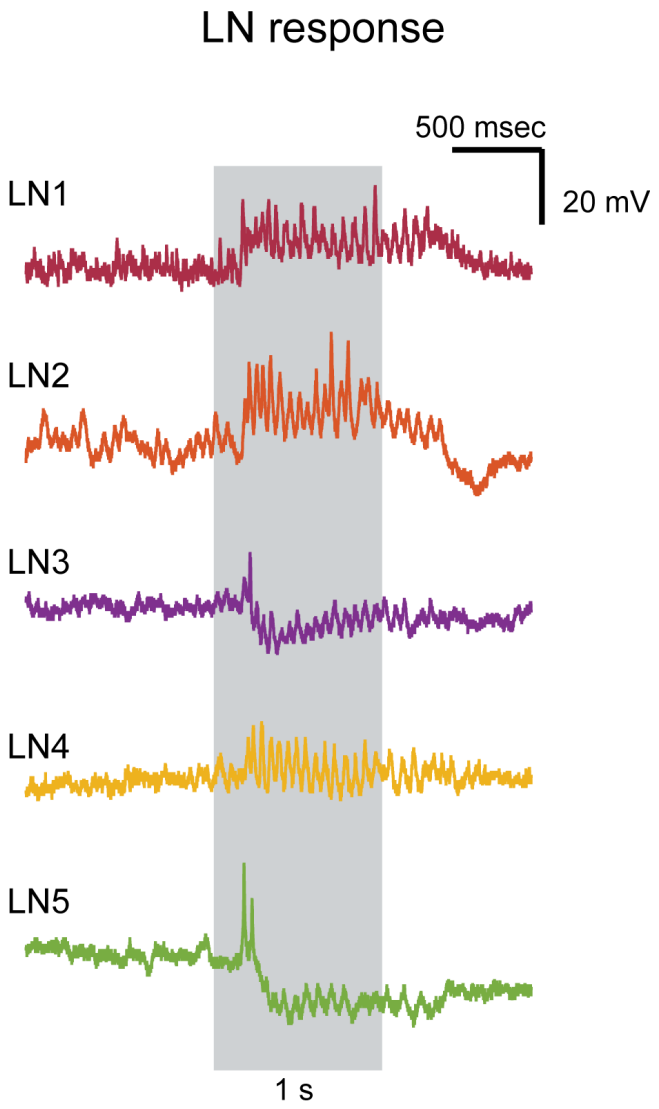


Onset and Offset Population Neural Responses Are Orthogonal

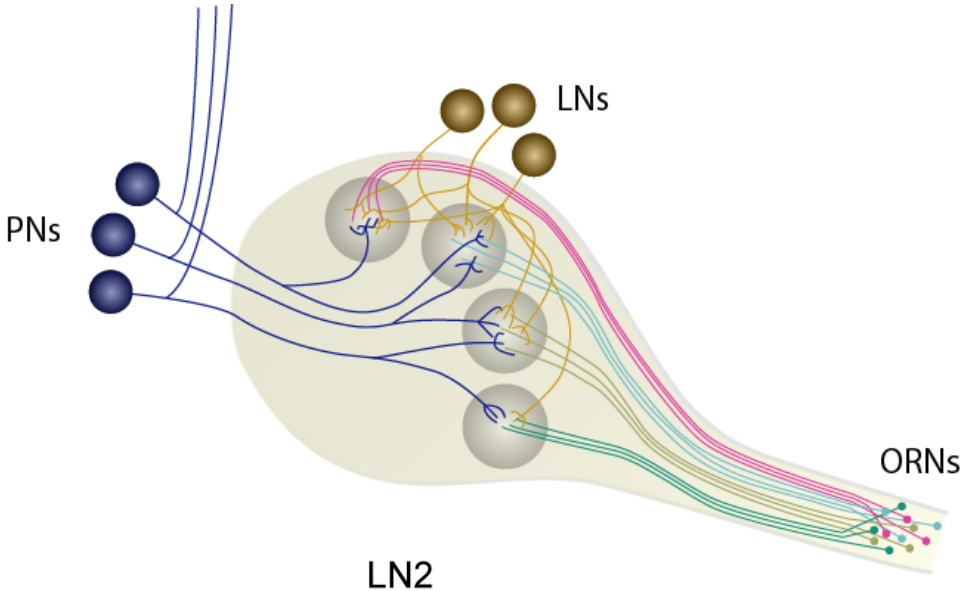


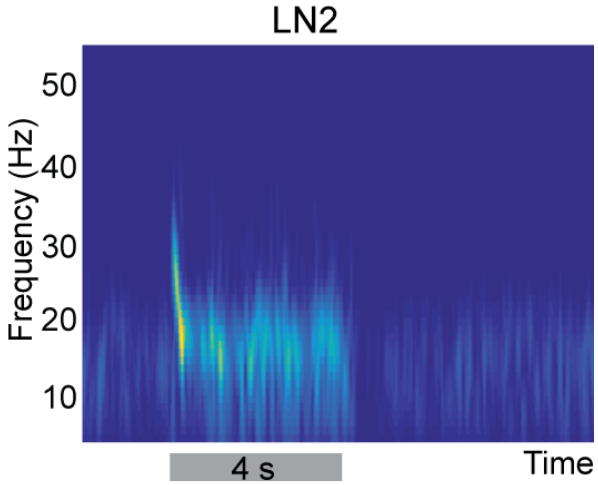
Local Neuron Responses During ON and OFF period

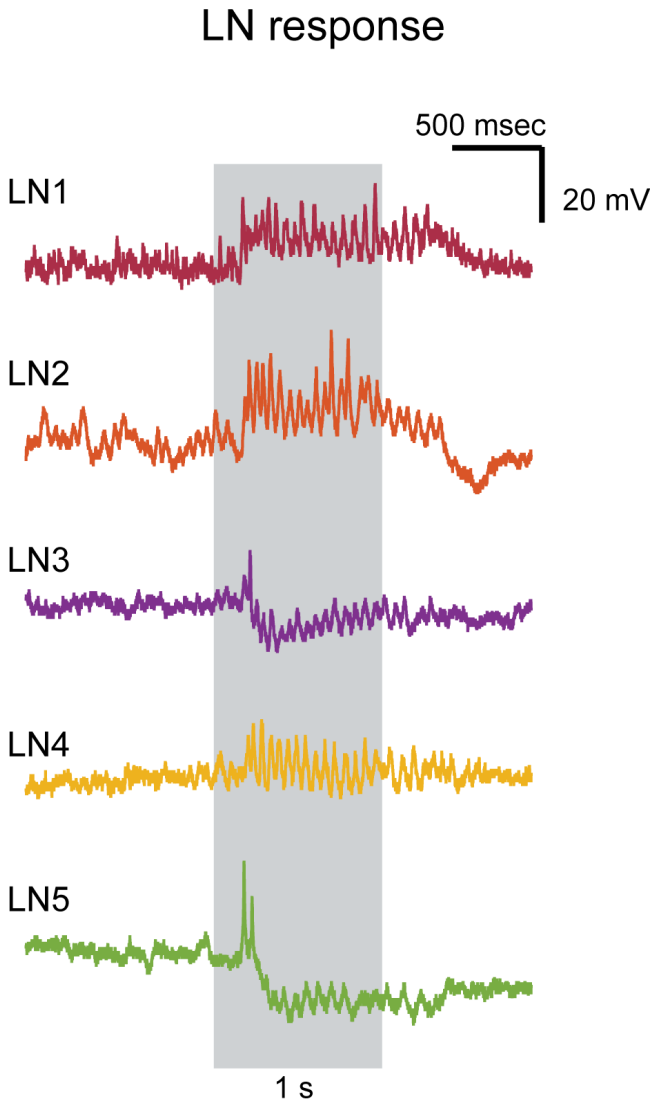




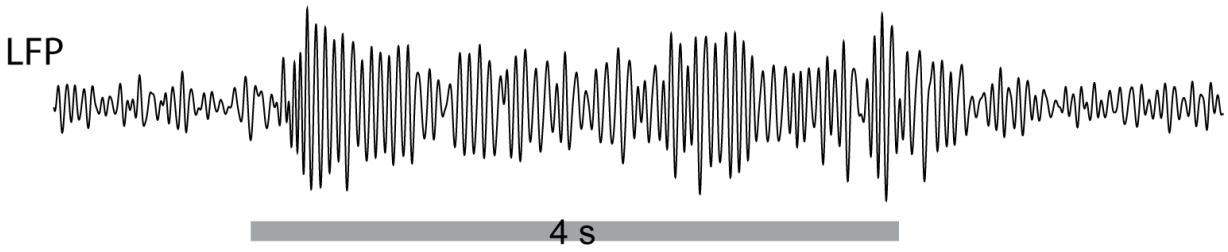
Local Neuron Responses During ON and OFF period

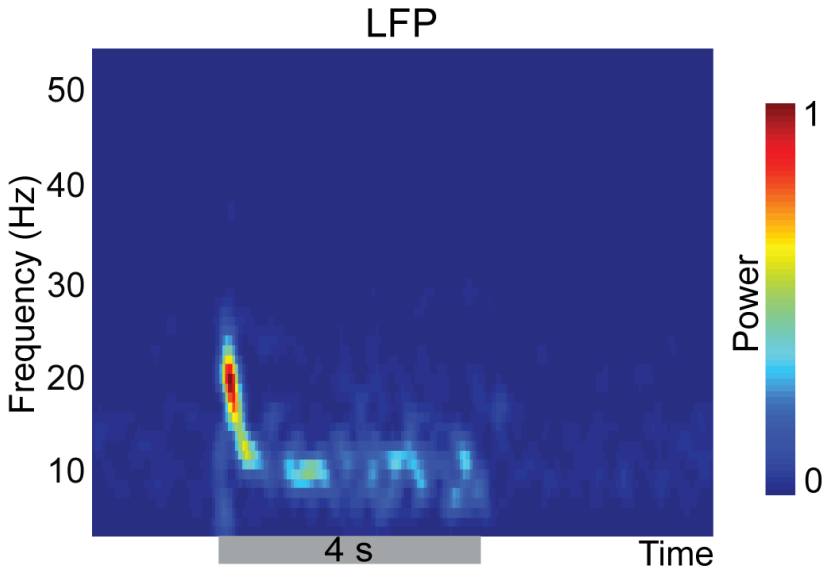




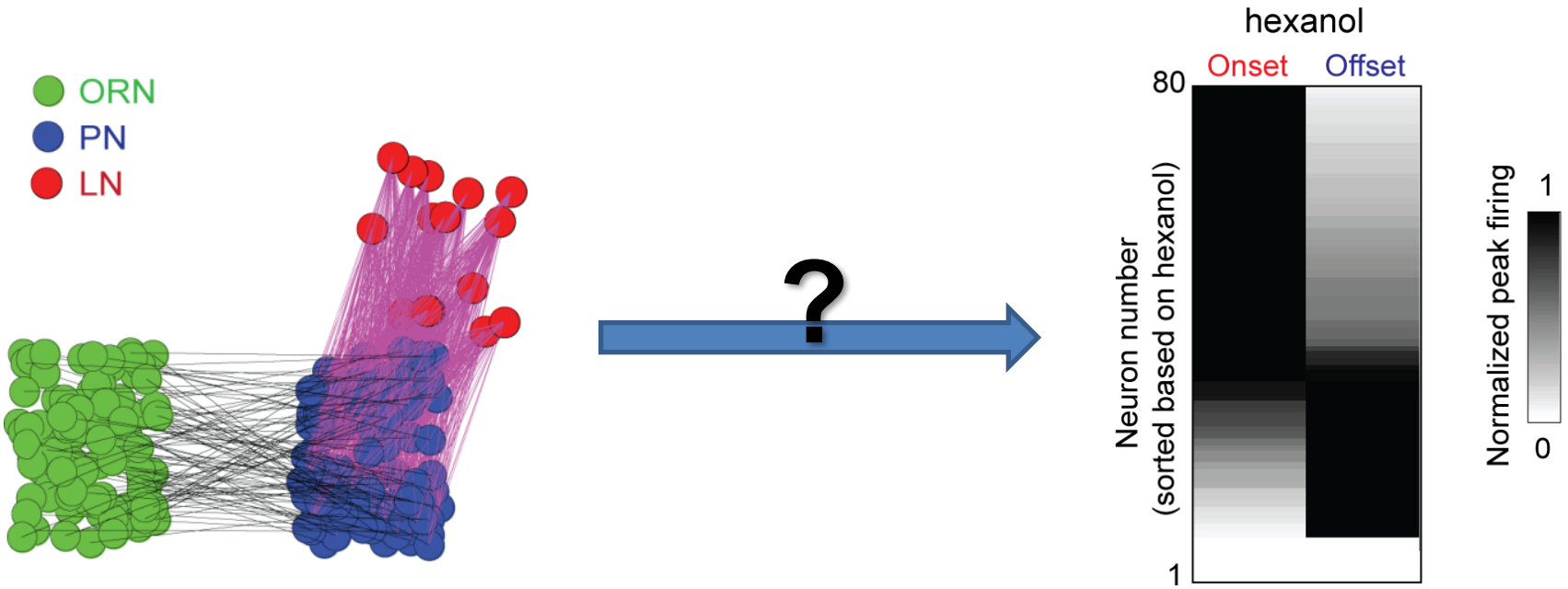


Local Field Potential During ON and OFF period

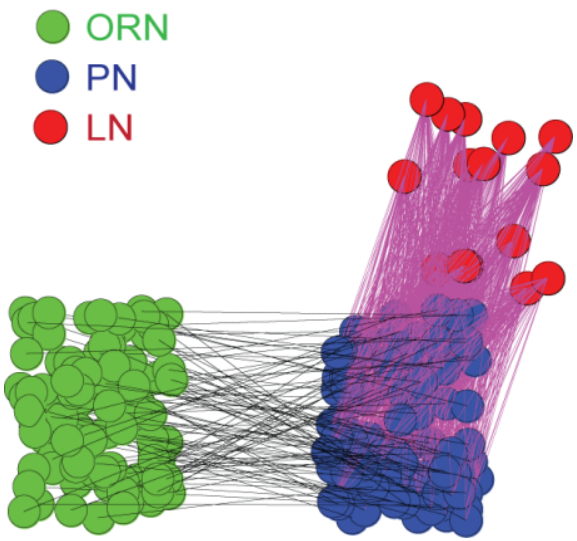




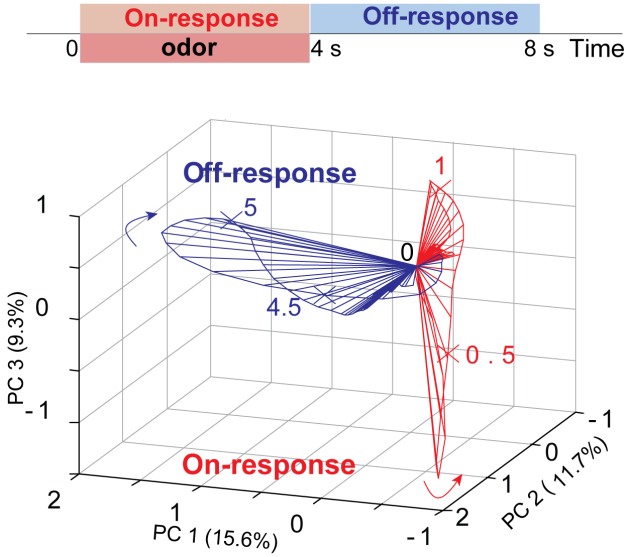
Problem


ORN
PN
LN
?
hexanol
Onset
Offset
80
1
Neuron number
(sorted based on hexanol)
Normalized peak firing
1
0

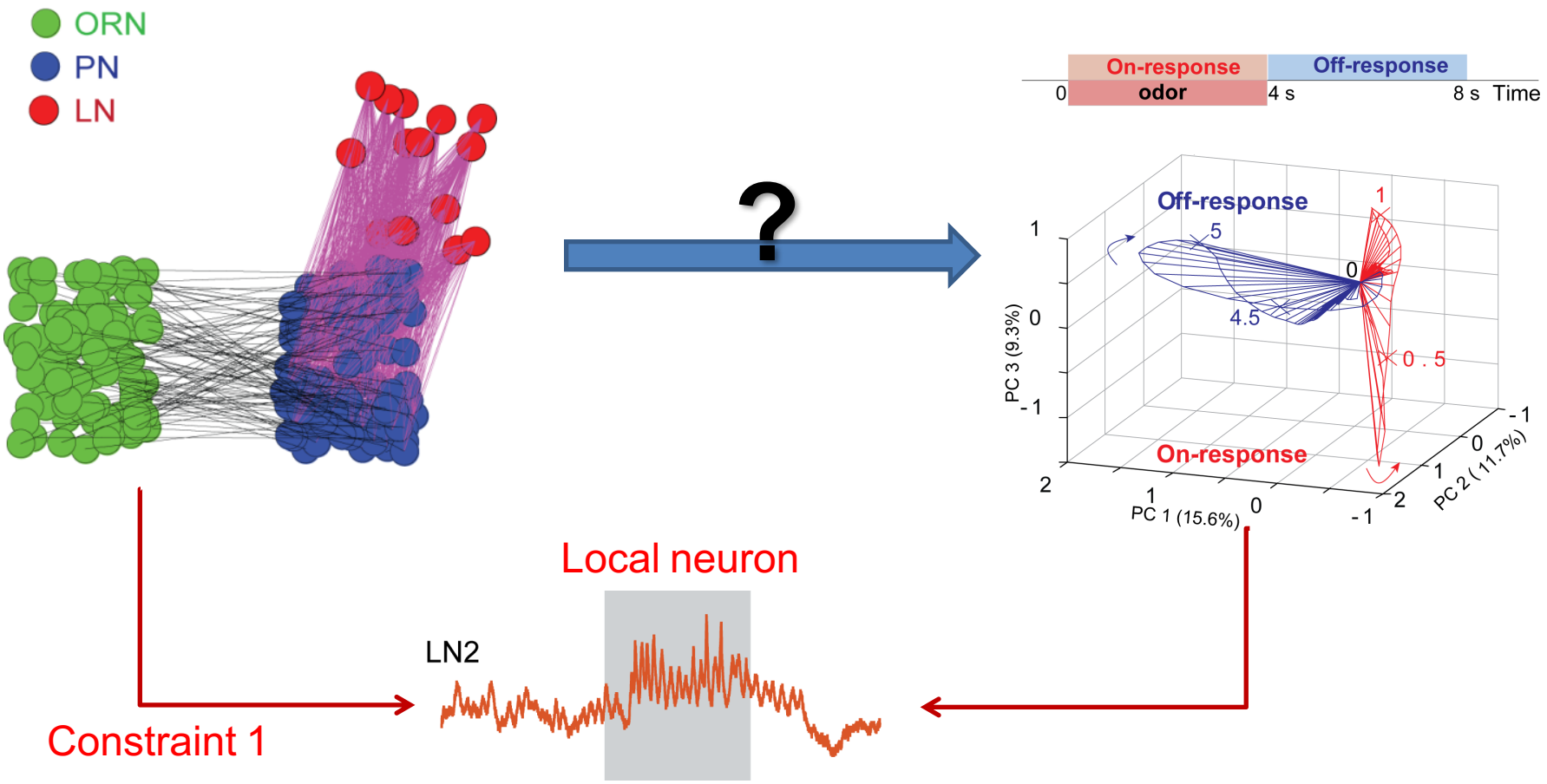
Problem


ORN
PN
LN


?


On-response
Off-response
0
odor
4 s
8 s
Time
Off-response
5
4.5
0
1
0 . 5
On-response
PC 3 (9.3%)
PC 1 (15.6%)
PC 2 (11.7%)

Problem Statement



Problem Statement