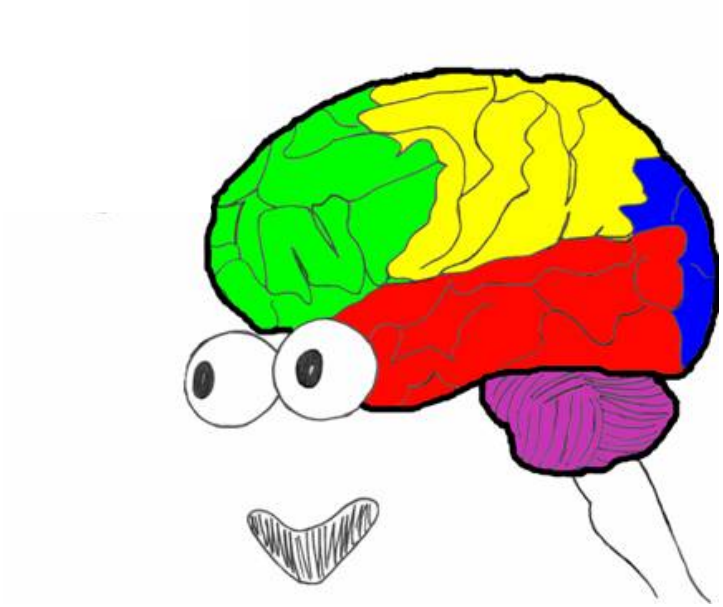
Spike triggered averages, revisited: success, failures, and the road to hierarchical neural coding



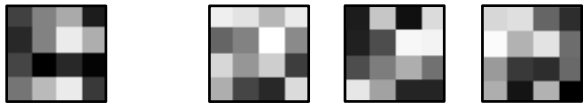
AMATH 342

Many thanks to Dr. Yasmine El-Shamayleh, Dr. Helen Sherk and Abishek De for slides and images

Spike triggered average (STA)

- Spike triggered ensemble: the set of all stimuli that evoked a spike

Spiking Stimuli:



$stim_1(x, y)$ $stim_2(x, y)$ …

$$\mathrm{STA}(x, y) = \frac{1}{\#\text{ of spikes}} \sum_{t \in \text{spike times}} stim_t(x, y)$$

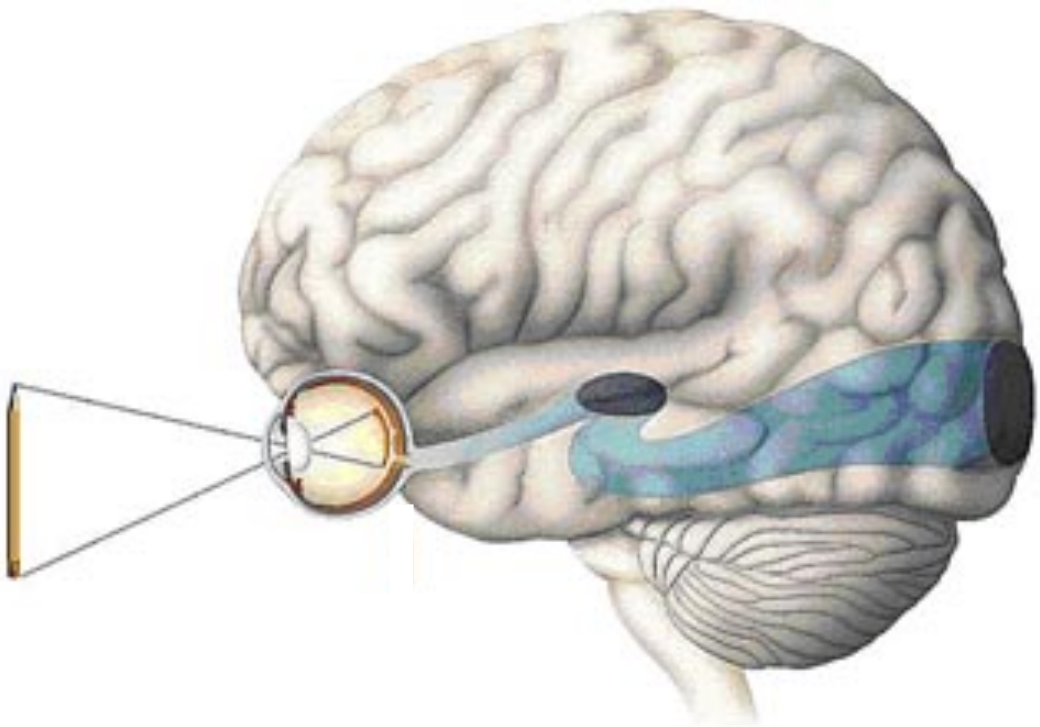
Spike triggered average (STA)

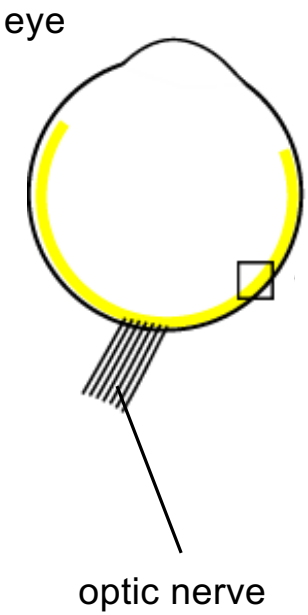
- Use STA as (optimal) filter to predict neural firing:

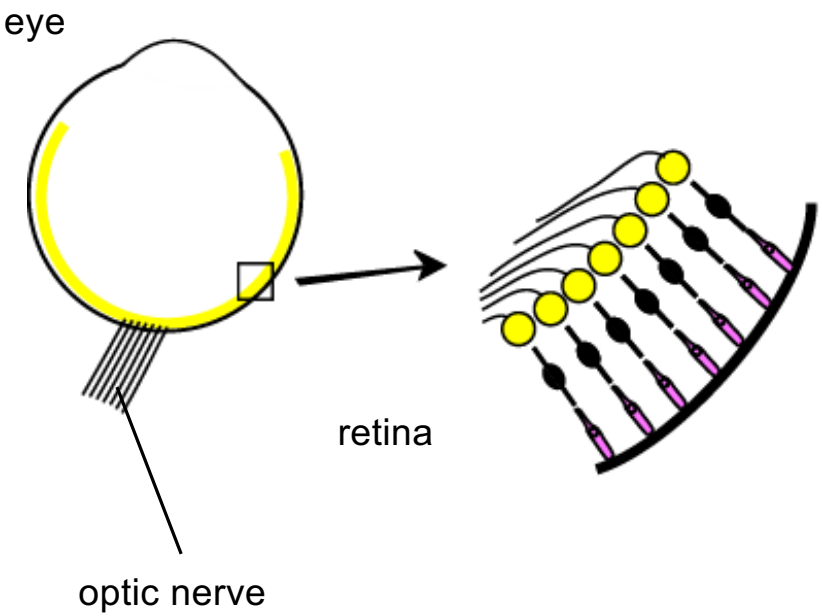
- Take a (brand new) stimulus stim(x,y) 
- Compute “dot product”

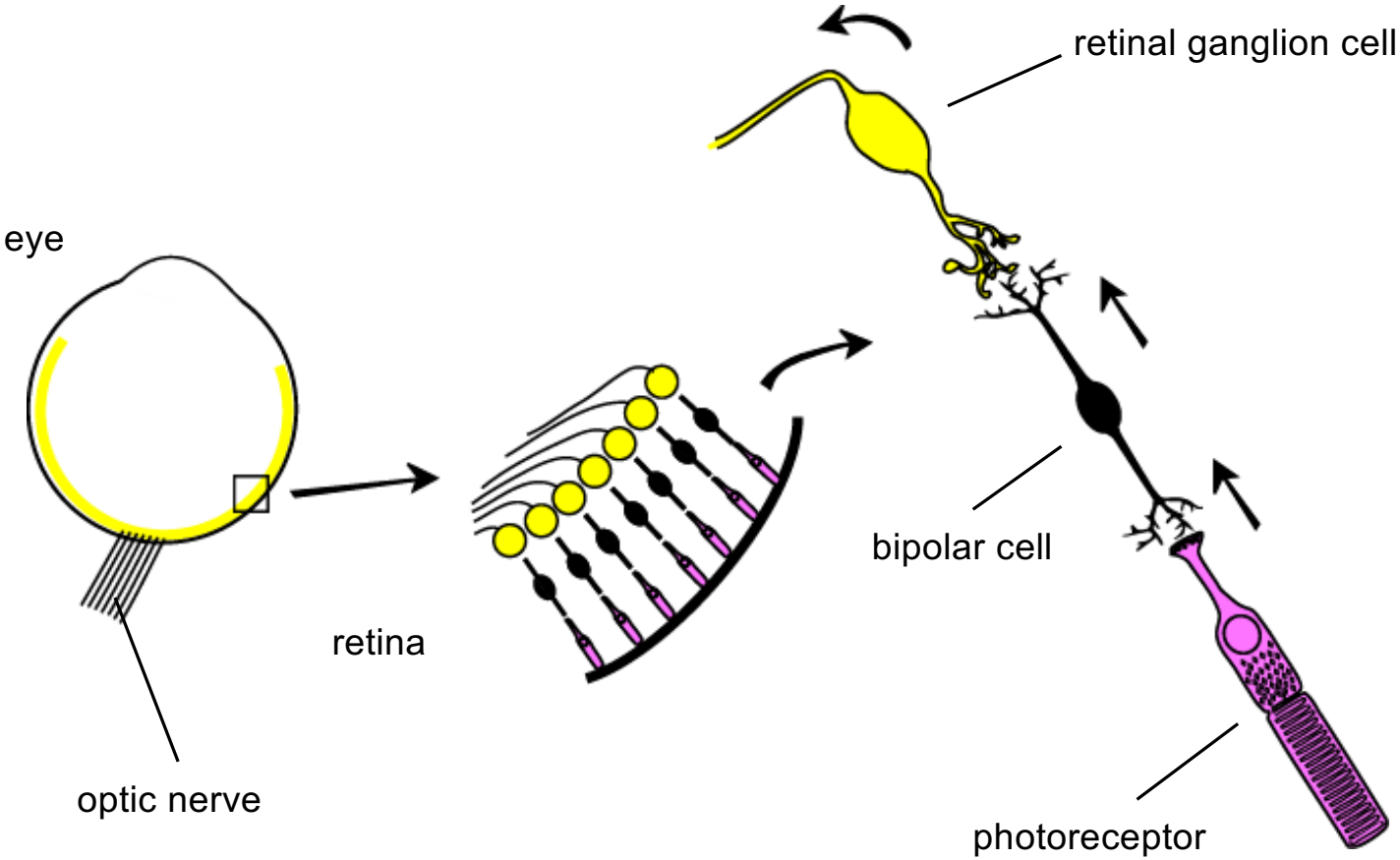
$$L = k \sum_{x,y} \mathrm{stim}(x,y) \times \mathrm{STA}(x,y)$$

- Use L as (linear) estimate of p(spike | stim(x,y))
- STA sometimes used interchangeably with more general term “receptive field“

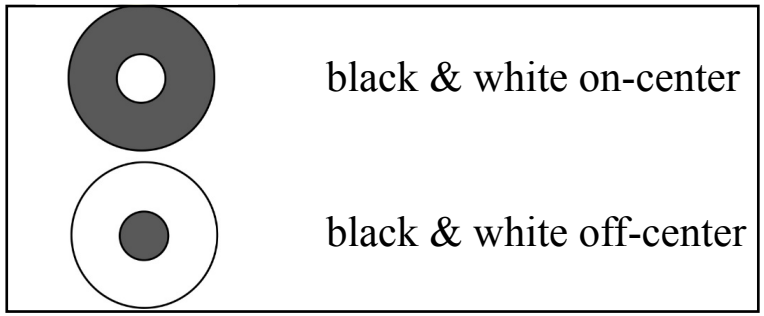



eye
optic nerve


eye
retina
optic nerve

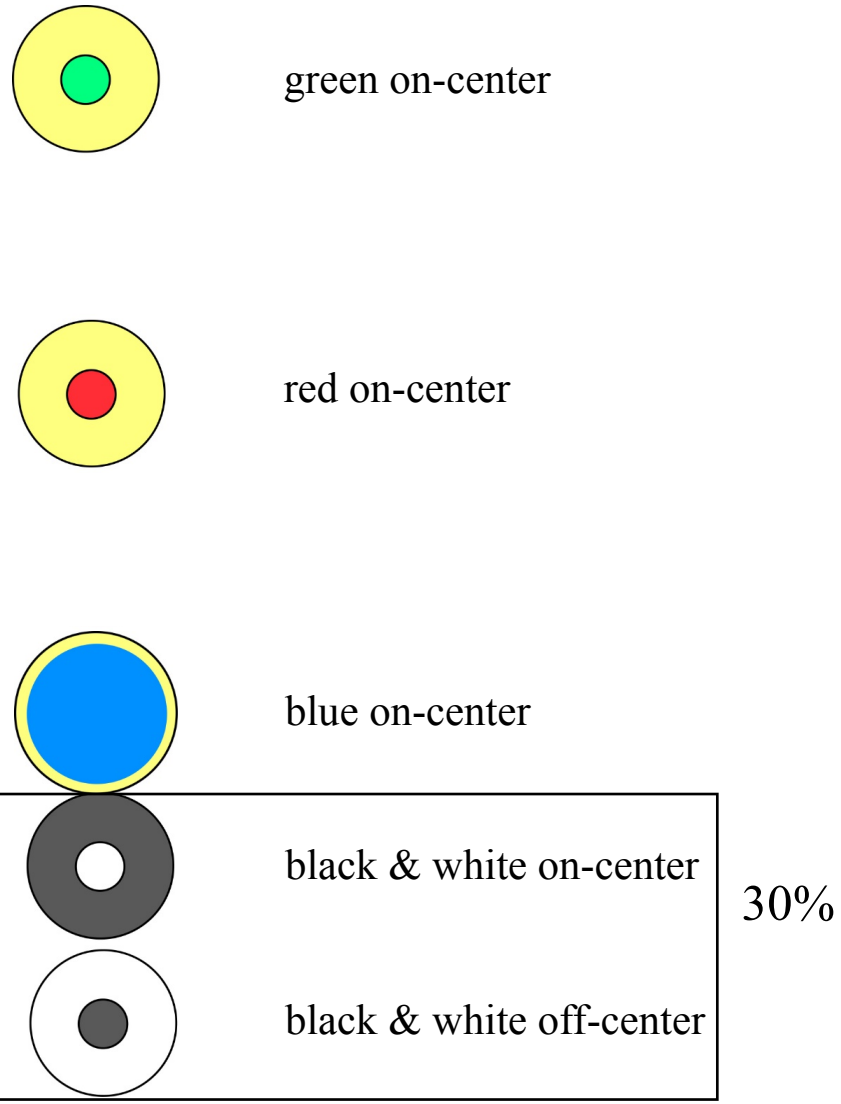

eye
optic nerve
retina
retinal ganglion cell
bipolar cell
photoreceptor

Retinal ganglion
cell receptive fields

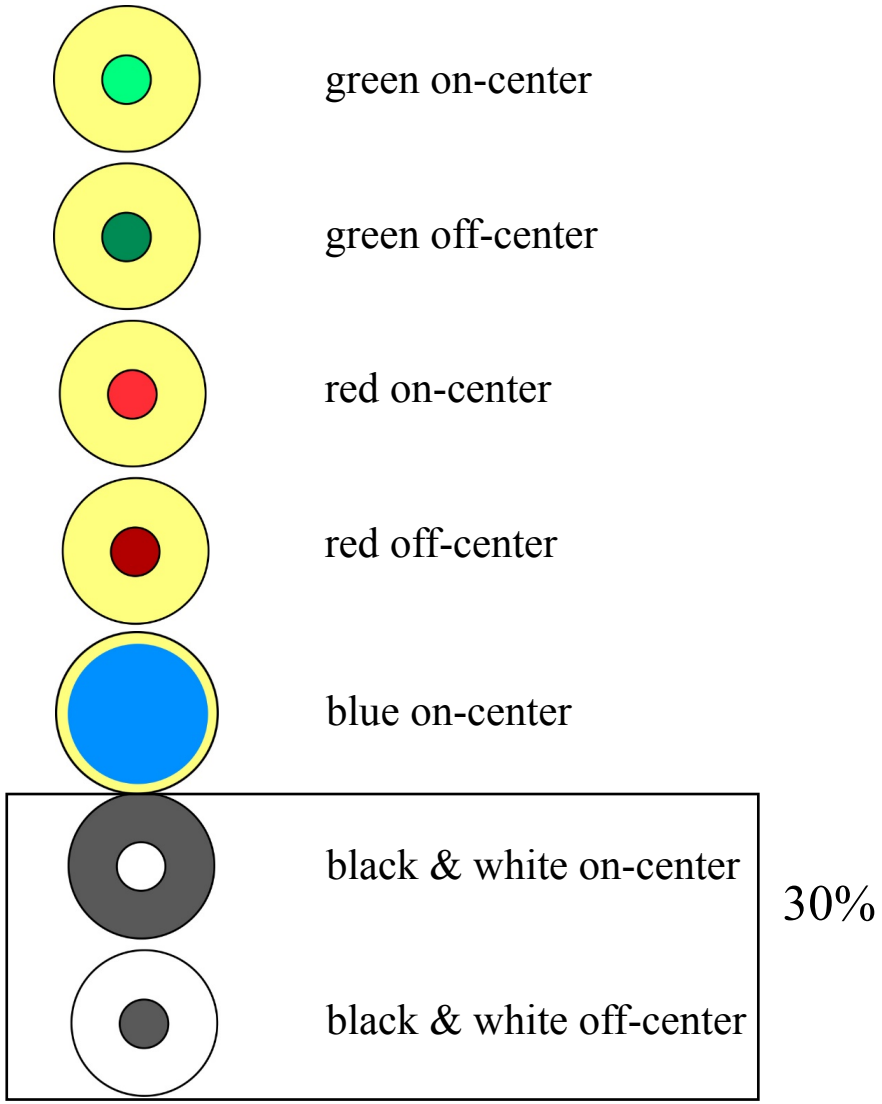


30%

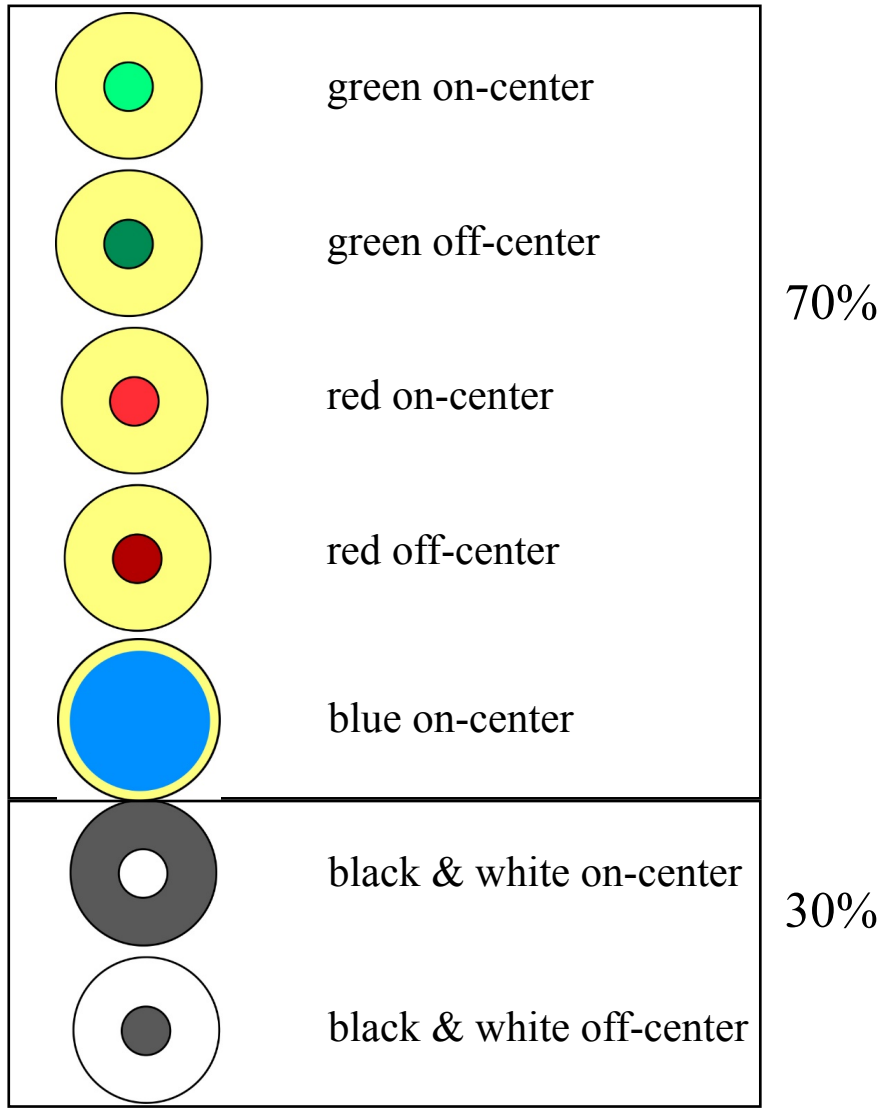
Retinal ganglion
cell receptive fields



Retinal ganglion
cell receptive fields



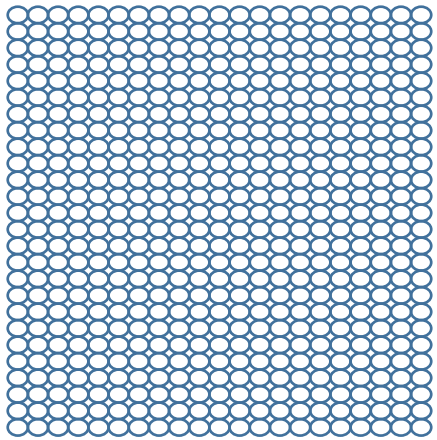
Retinal ganglion
cell receptive fields



“What” are the RGCs doing ?

Input image
(cornea)

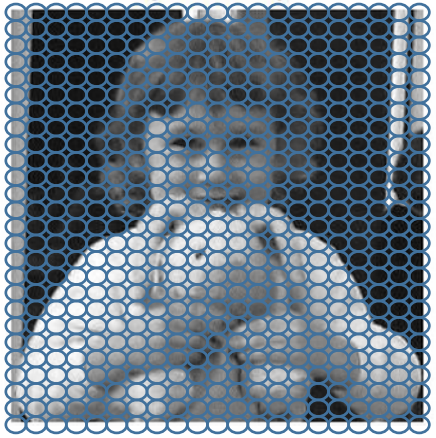
Input image
(cornea)



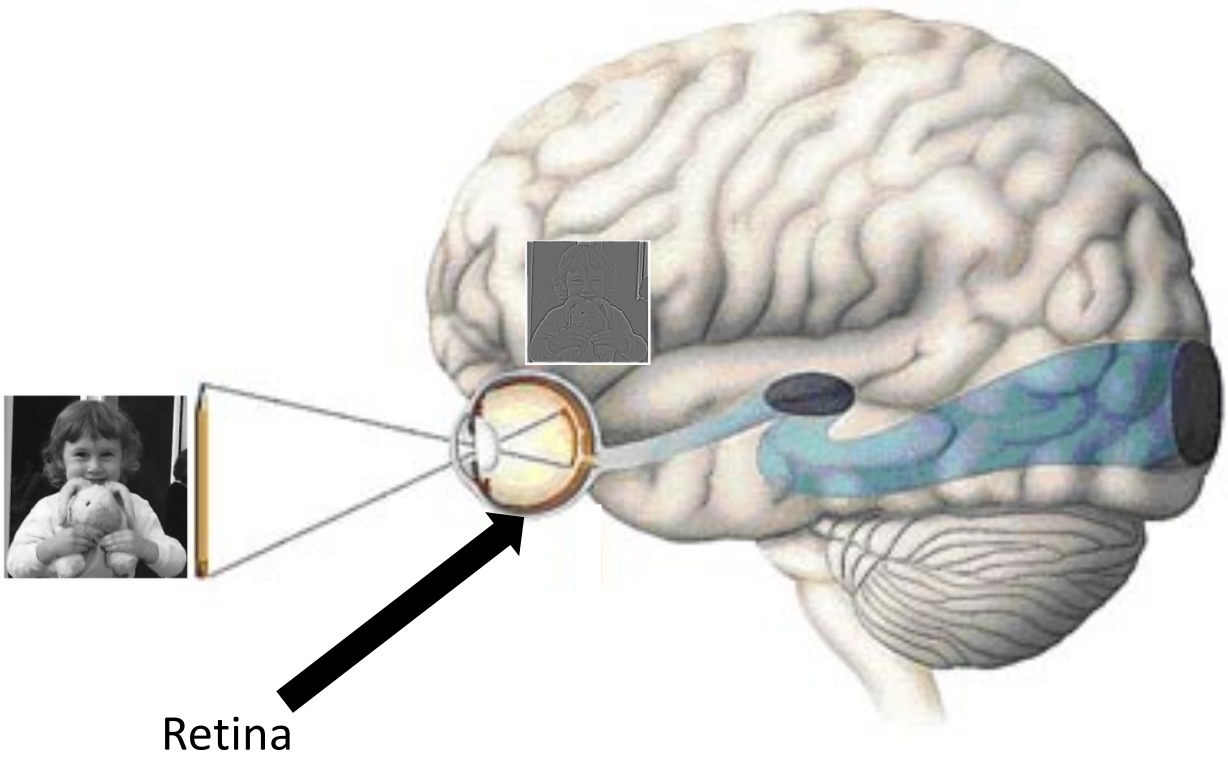
RETINA

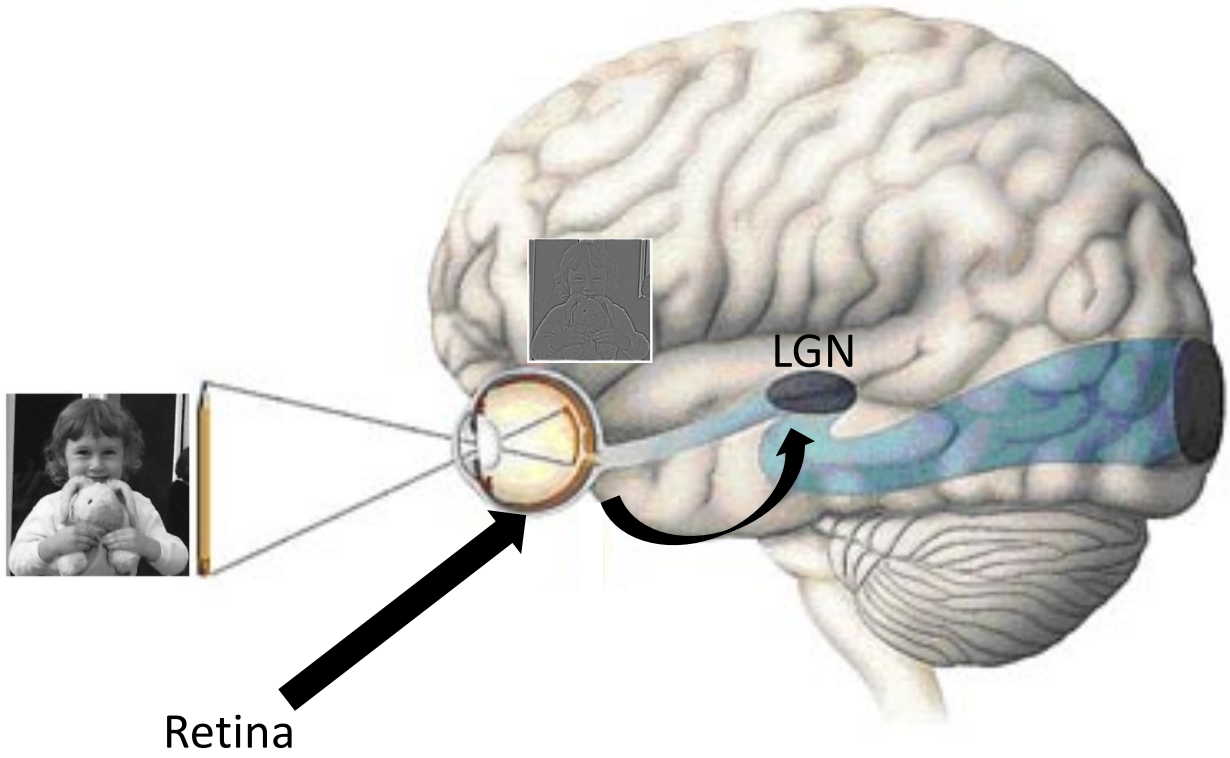
Retinal ganglion cells respond to edges

Input image
(cornea)

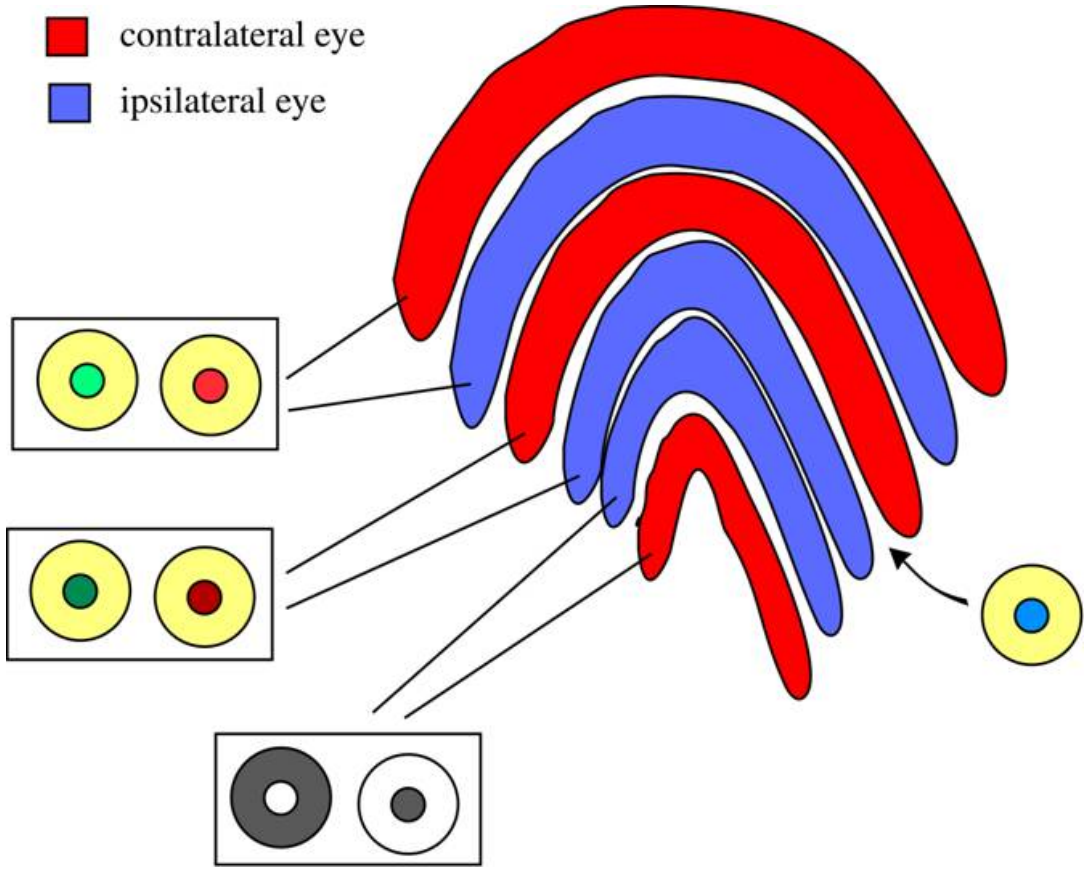


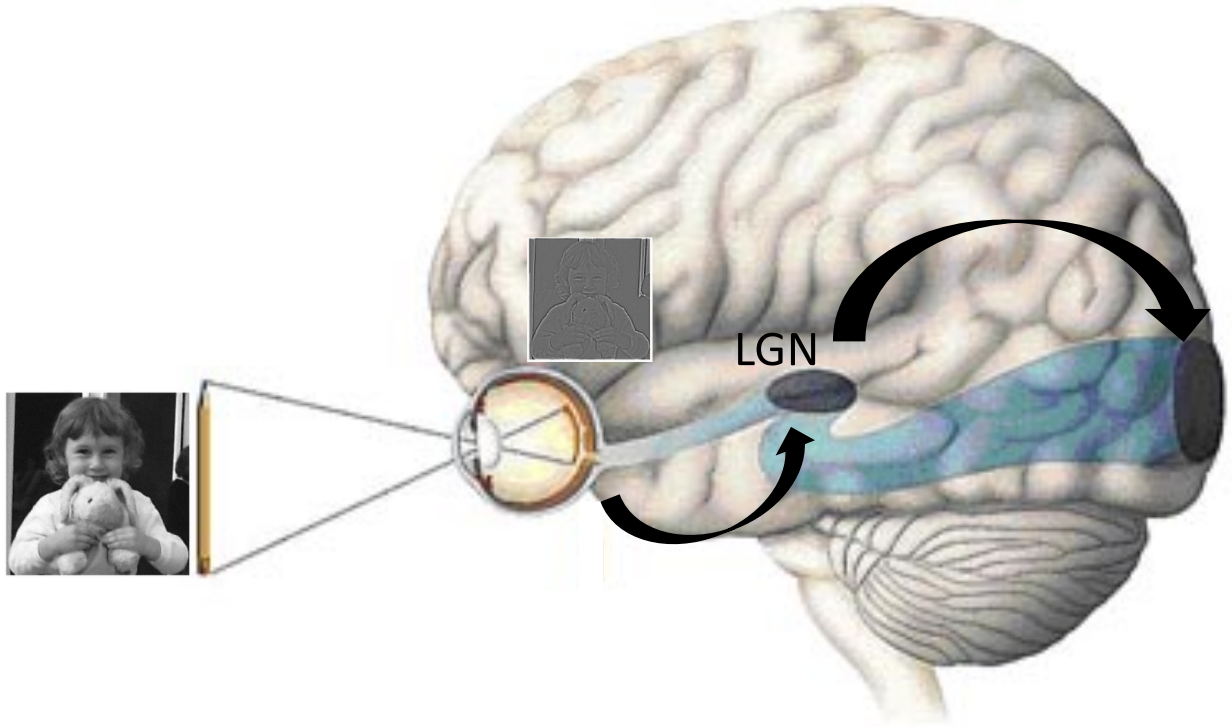
"Neural image"
(retinal ganglion cells)


Retina

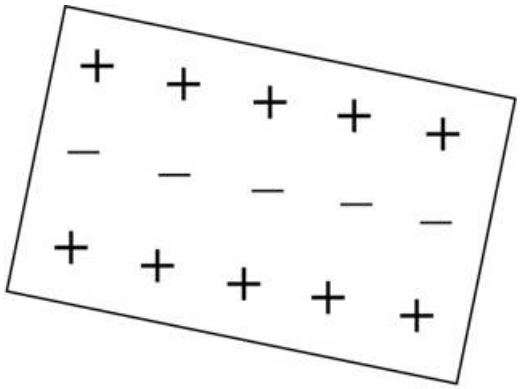

LGN
Retina

LGN has similar receptive field structure as retinal ganglion cells

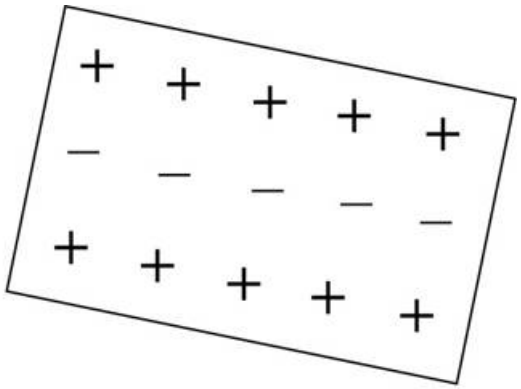



LGN
Area V1
Primary Visual Cortex

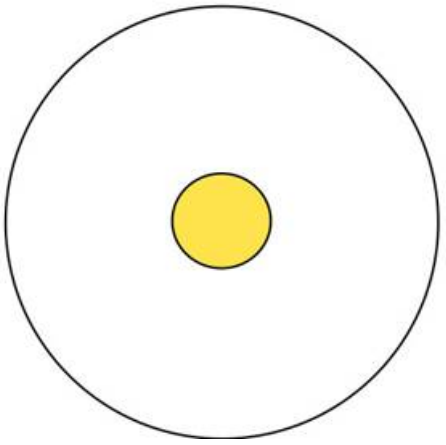
simple cell receptive field



simple cell receptive field



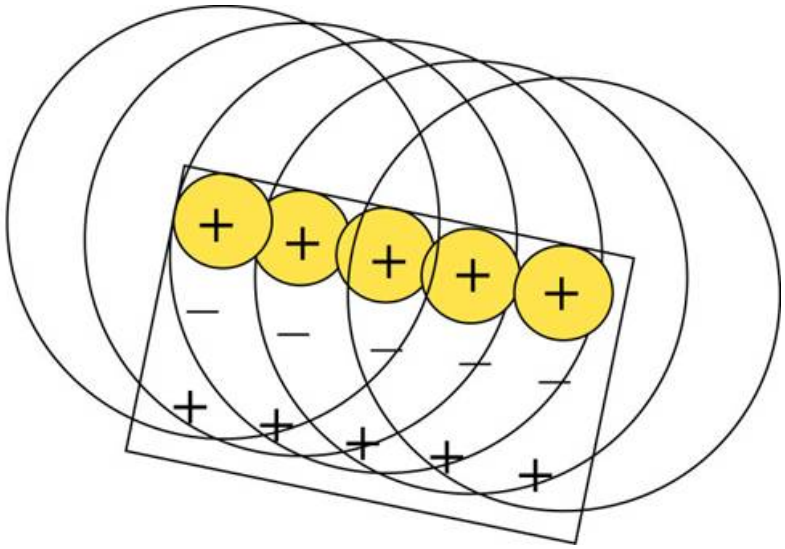
LGN cell receptive field



How is receptive field structure of simple cell derived from LGN cells?

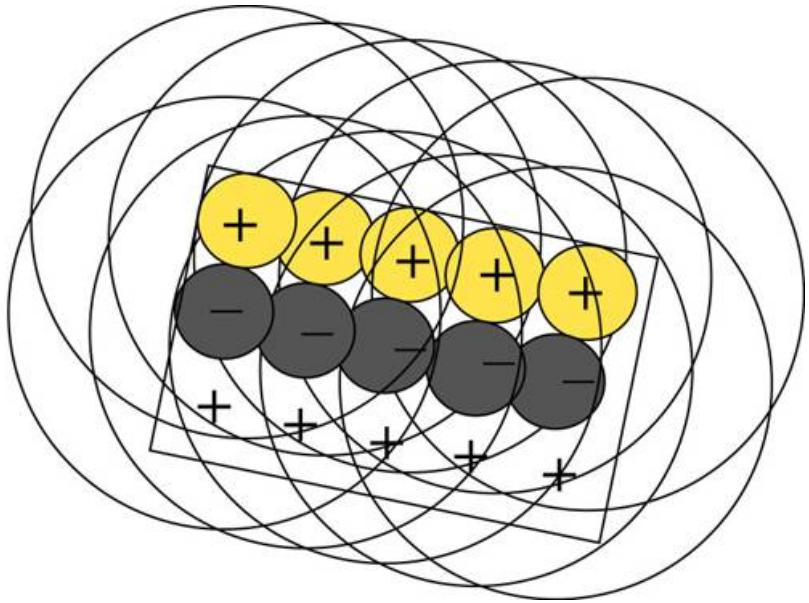
Many LGN cells project to a simple cell to form elongated receptive field structure

simple cell receptive field



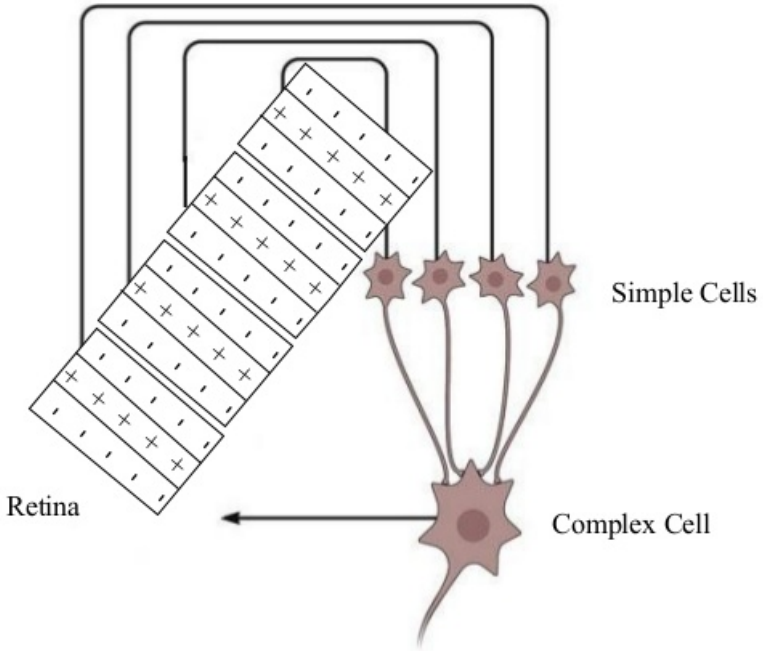
Many LGN cells project to a simple cell to form elongated receptive field structure

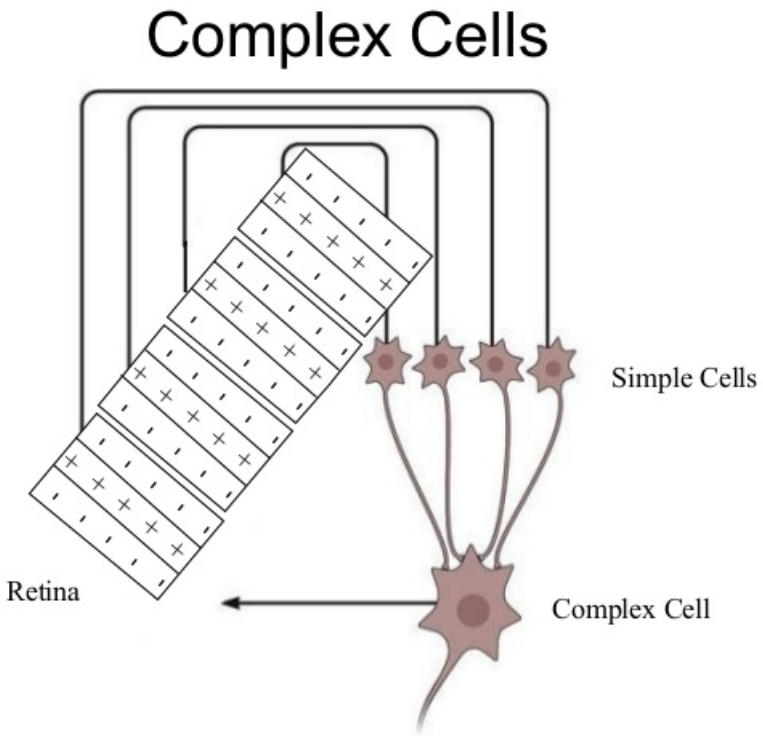
simple cell receptive field



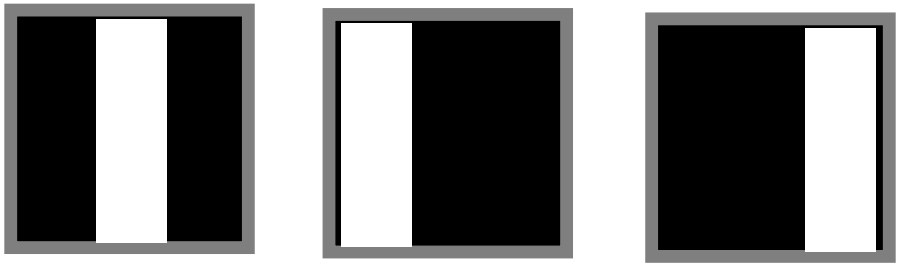
Complex Cells

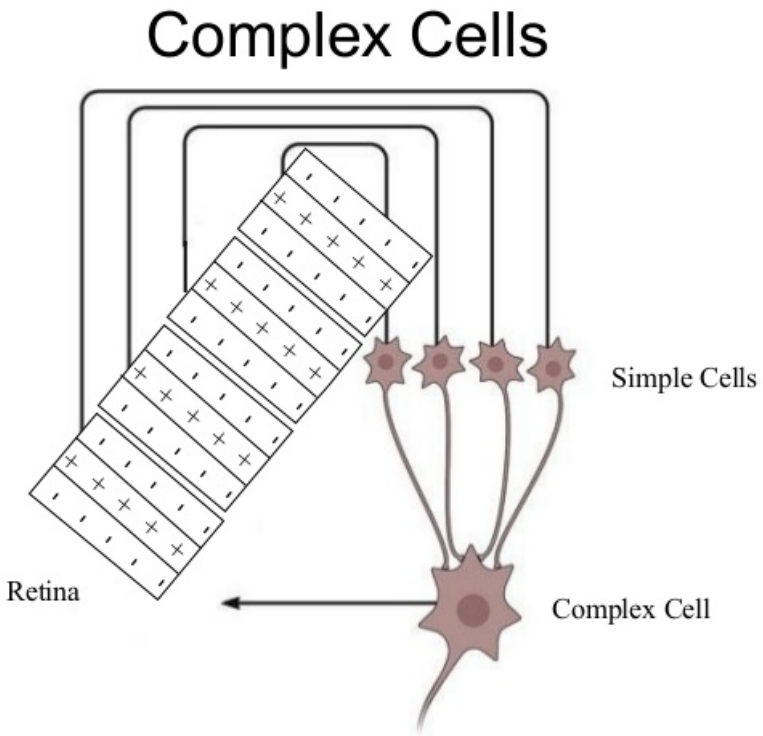
… are also found in V1 … and cause STA to fail!



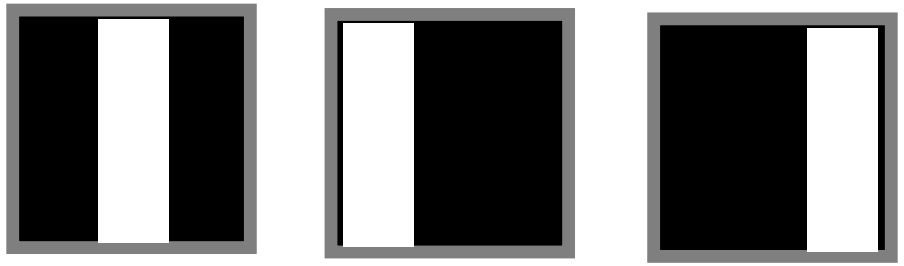


Spike triggered ensemble:





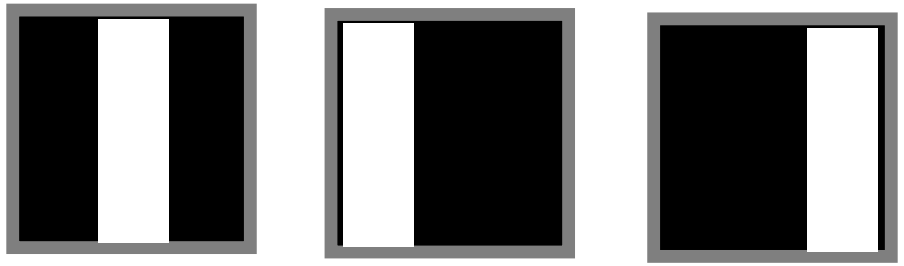
Spike triggered ensemble:



Spike triggered average:

Not informative!

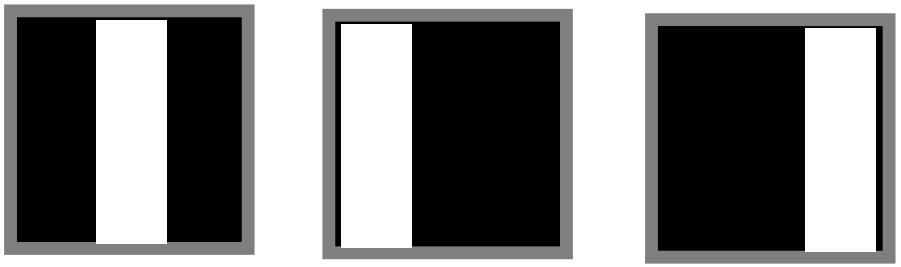
Spike triggered ensemble:



Ways forward: cortical coding

1. Spike triggered *covariance*

Spike triggered ensemble:



Ways forward: cortical coding

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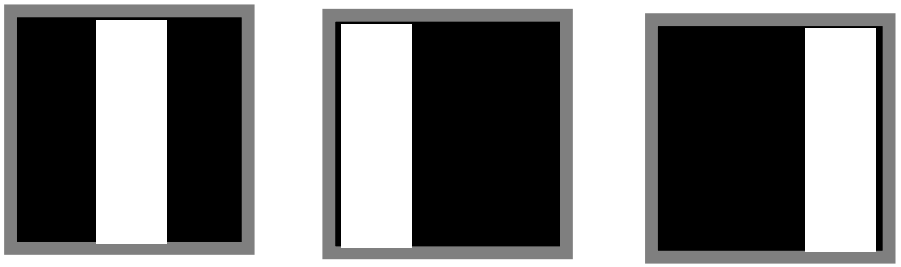

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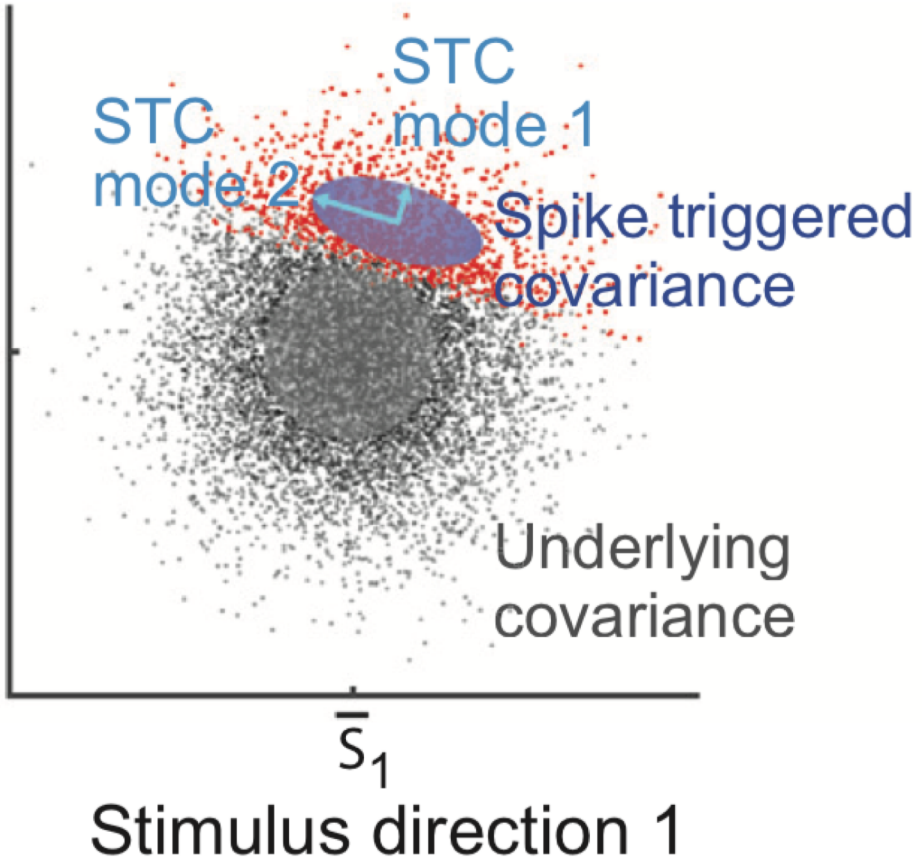
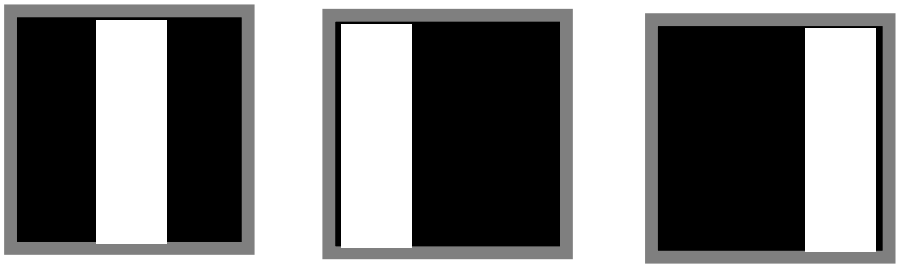


Aljadeff, Fairhall et al, Neuron, 2016

Spike triggered ensemble:



Ways forward: cortical coding

2. Hierarchical modeling