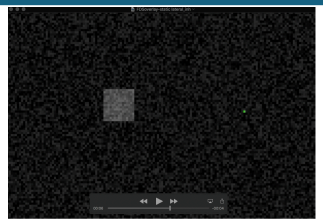
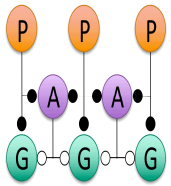
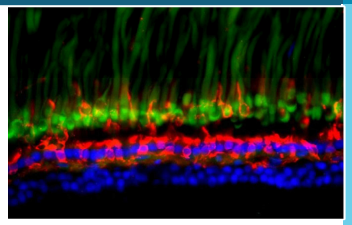
SAND2018-8020C

Retinal-Inspired Algorithms for Detection of Moving Objects







PRESENTED BY

Frances S. Chance and Christina E. Warrender

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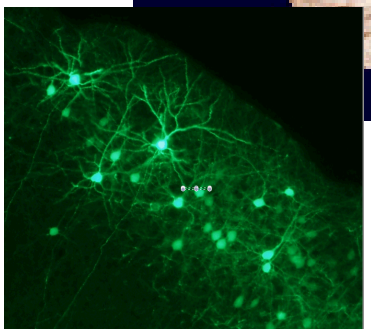
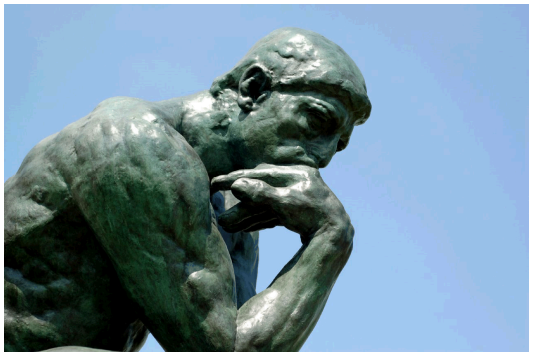
WHY THE RETINA

Typical approach to neural-inspired algorithms and architectures….
How does the brain produce behavior and cognition?





WHY THE RETINA

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- The circuit is relatively well understood

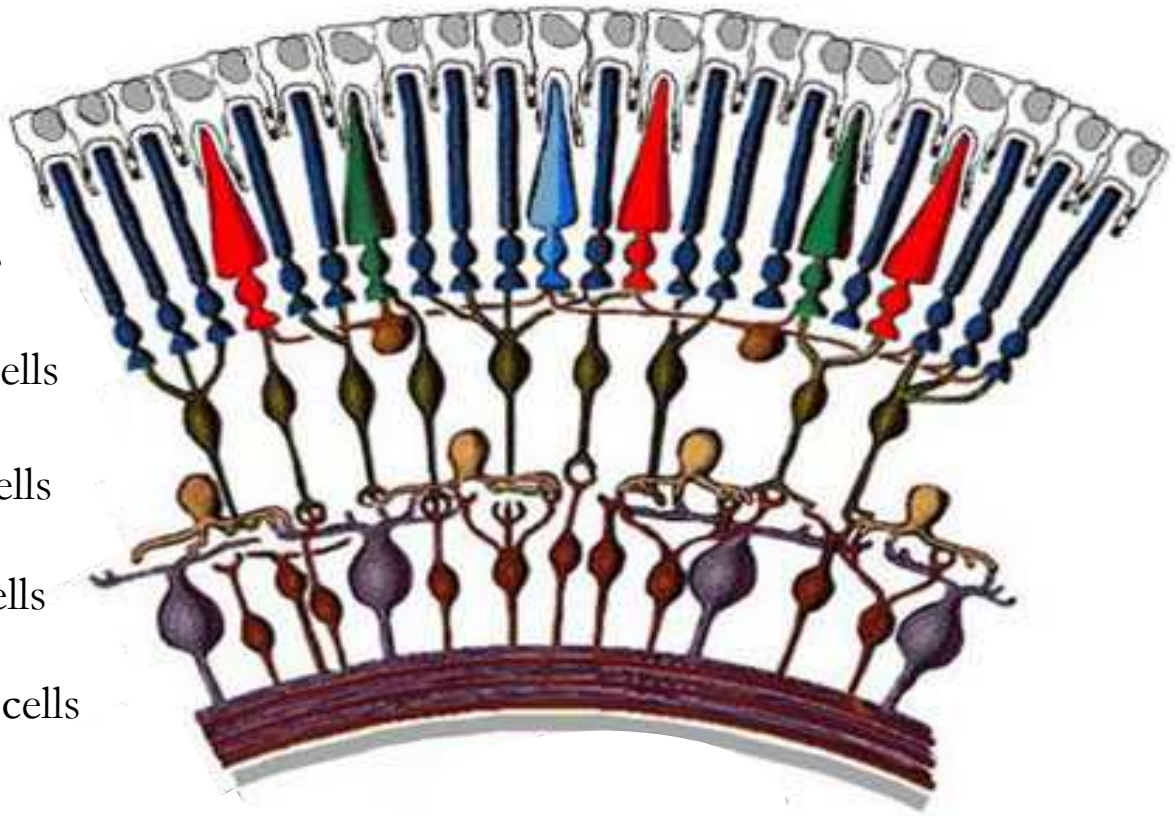
photoreceptors

horizontal cells

bipolar cells

amacrine cells

ganglion cells



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- In spite of relative simplicity, interesting basic computations

- Effectively "pre-processes" visual input, down-selecting information to be sent to the brain

  - specific features are selected for transmission

  - irrelevant features are filtered out

WHY THE RETINA

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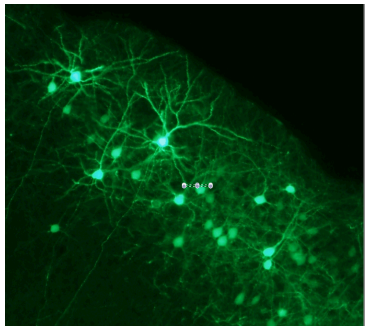
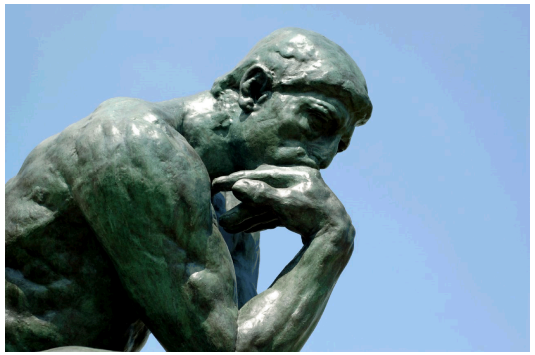
- Effectively "pre-processes" visual input, down-selecting information to be sent to the brain

- Pre-processing supports visual processing in the brain

WHY THE RETINA

How do neural circuits produce behavior?

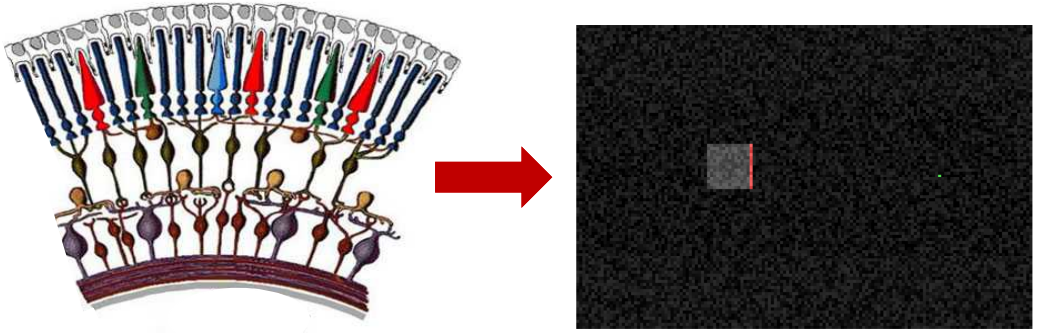




WHY THE RETINA

How do neural circuits produce behavior?

How does the retinal circuit produce interesting computation?



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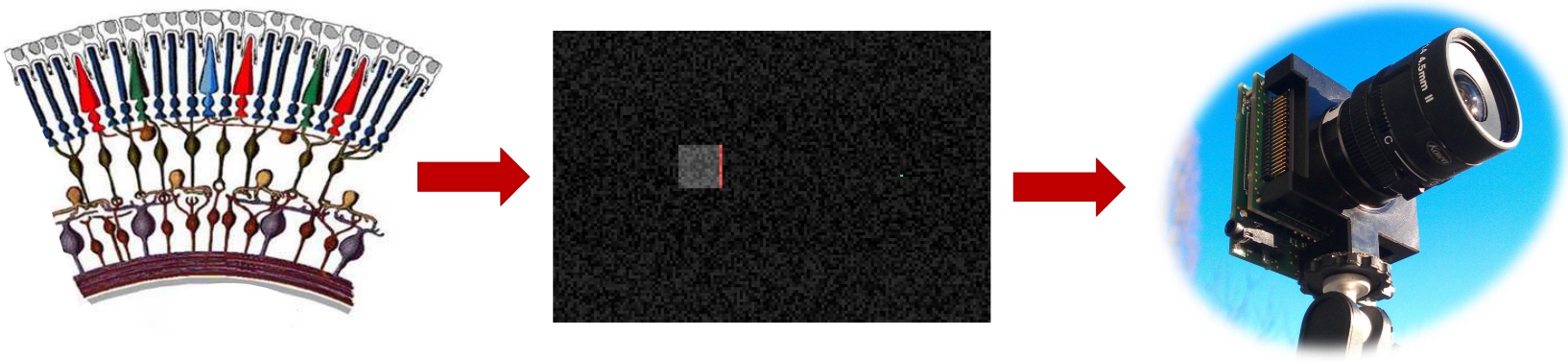
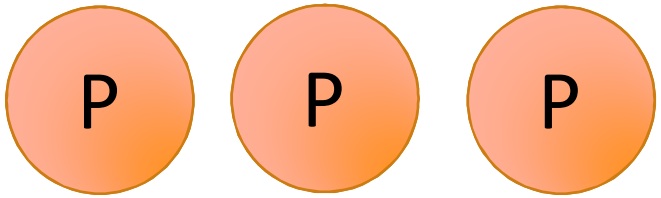


figure from inilabs.com

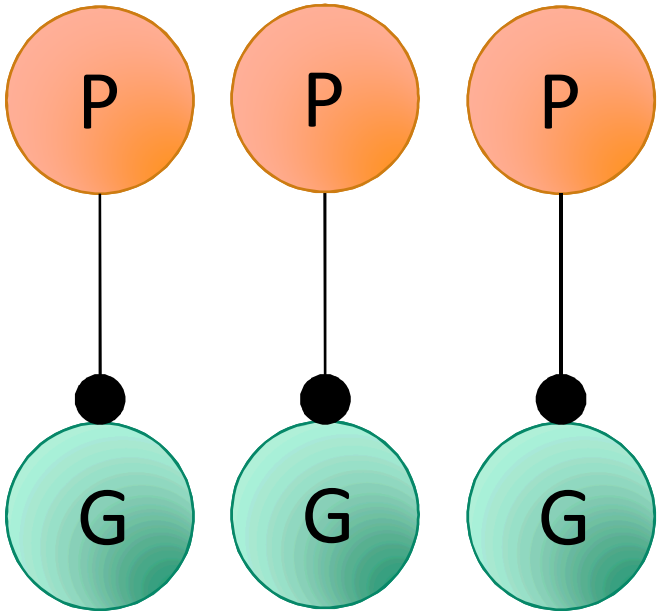
RETINAL MODEL: Photoreceptors and ganglion cells



Photoreceptors (aka pixels/bipolar cells):

- detect luminance changes at a location in space
- response is thresholded (ON-responses only)

RETINAL MODEL: Photoreceptors and ganglion cells



'ON' pathway photoreceptors

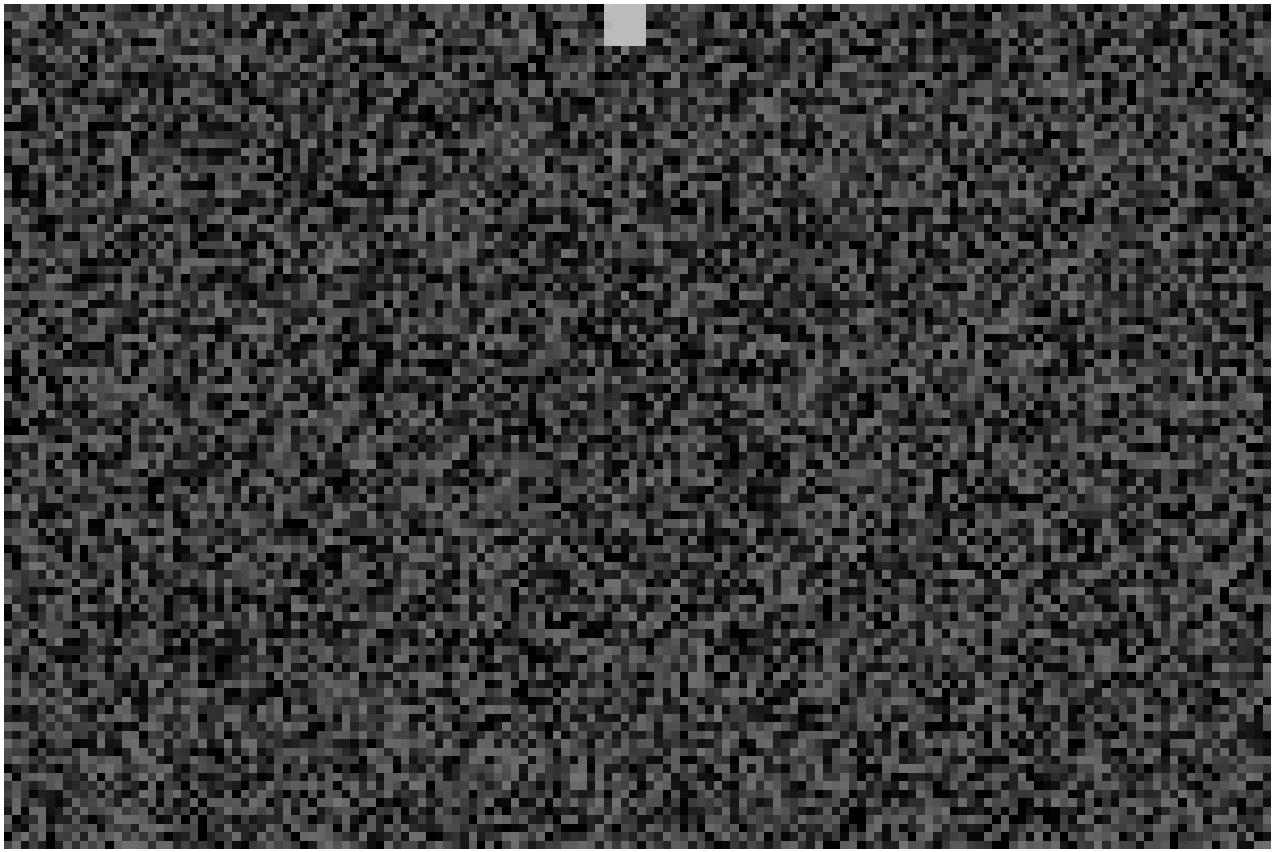
● = excitatory synapse

Thresholded ganglion cell responses (spiking)

So far, this model is similar to **ON-event detection** (e.g. DAVIS240)

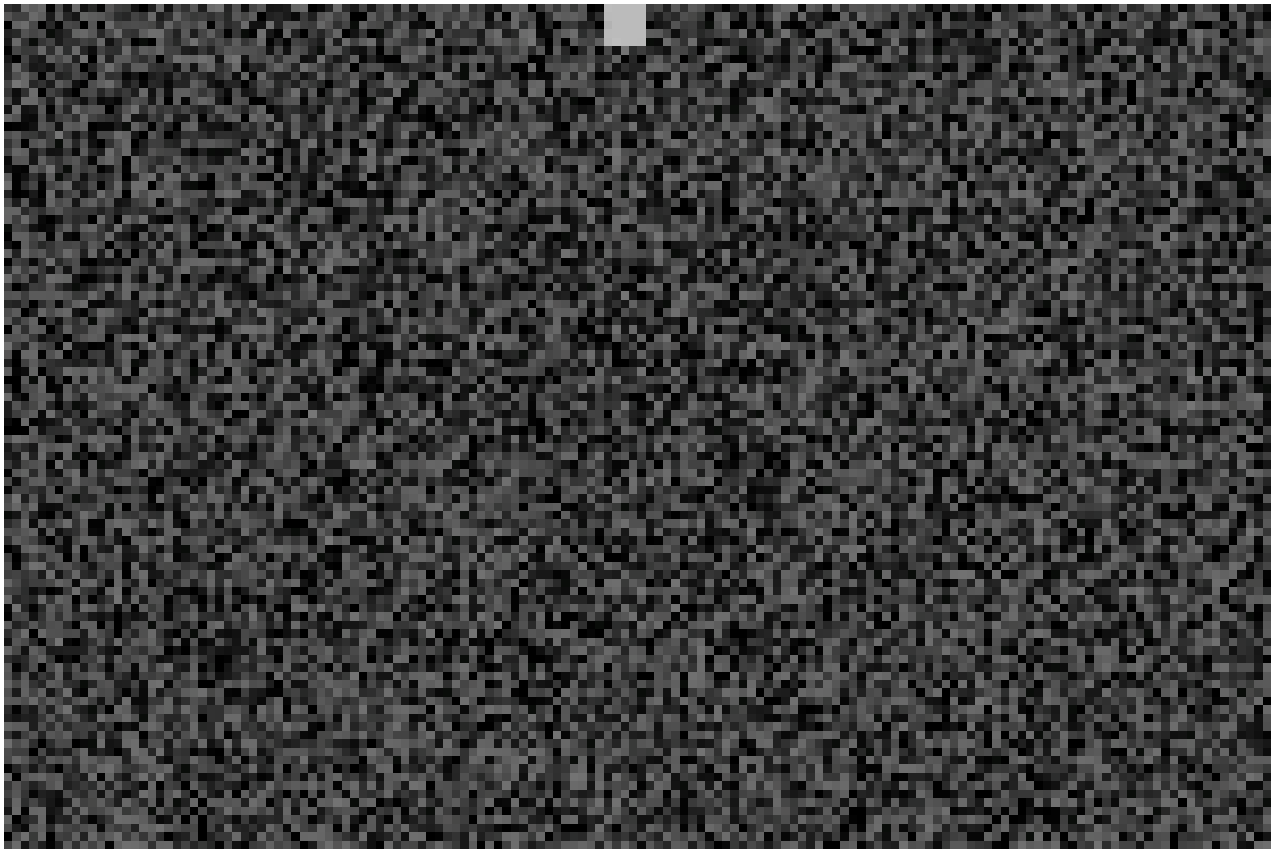
PROBLEM: Detect small moving target against noisy background

"easy" target



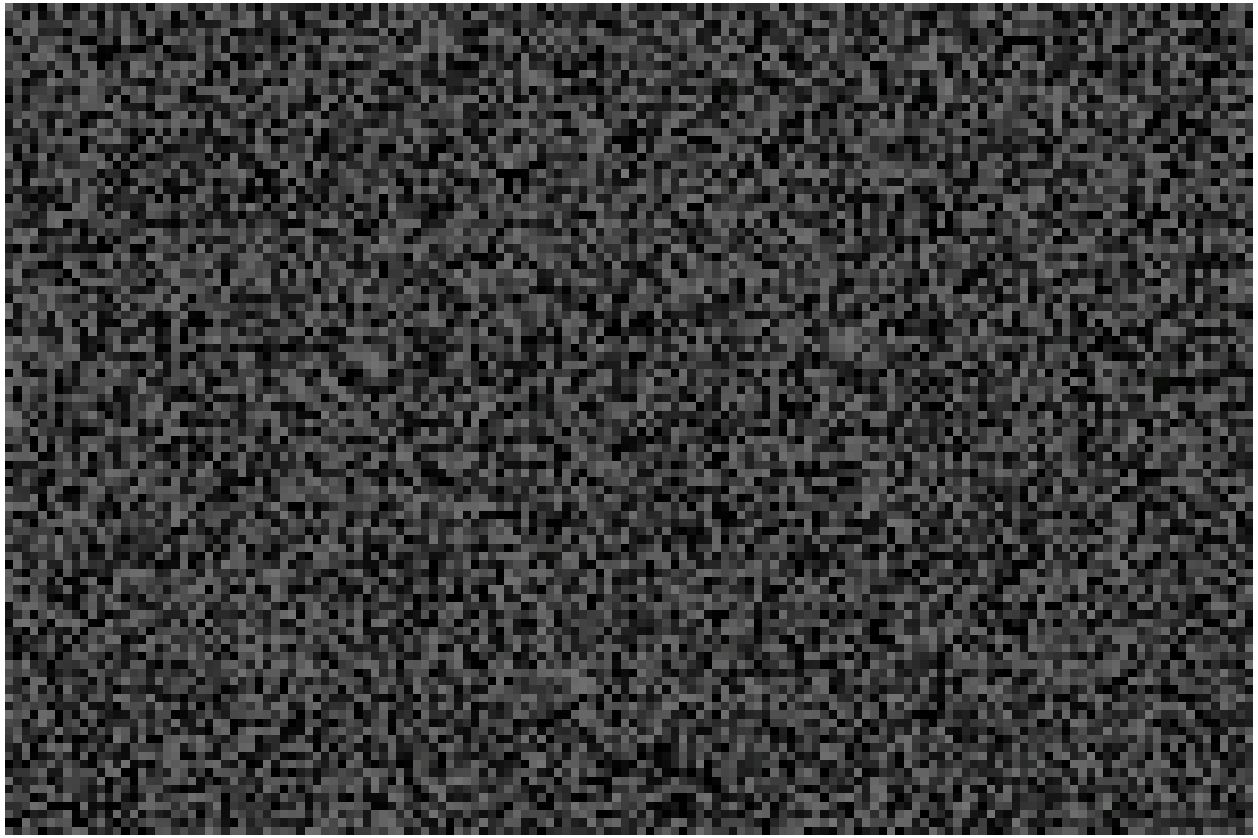
PROBLEM: Detect small moving target against noisy background

"easy" target, ON-responses in green

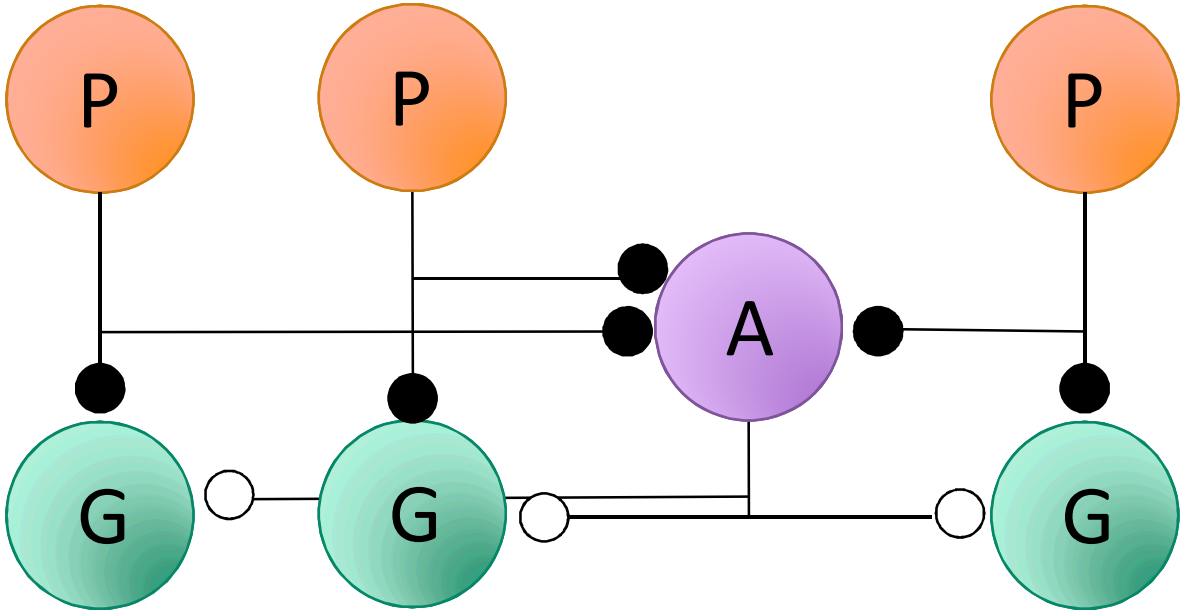


PROBLEM: Detect small moving target against white noise background

"Difficult" target = small and dim



OBJECT-MOTION SENSITIVE CELL



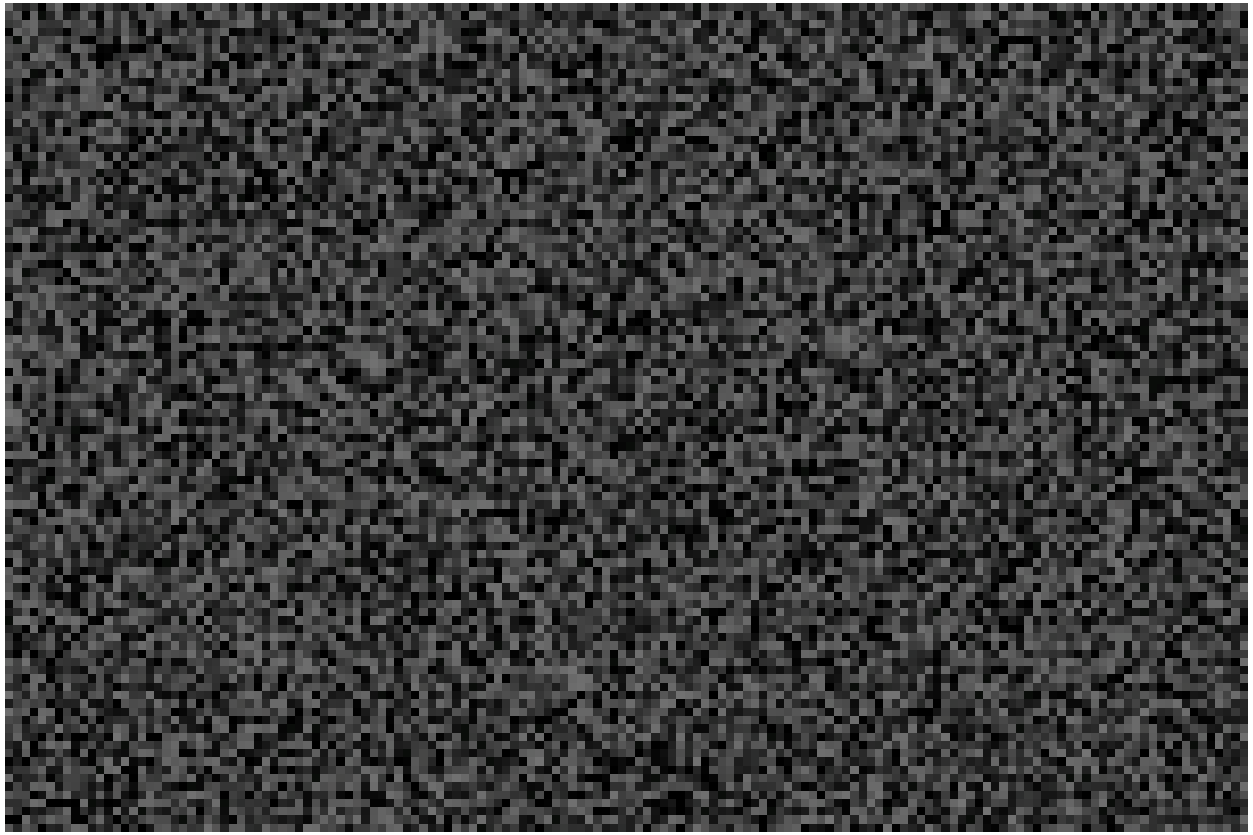
Model includes "global" inhibitory signal (amacrine cell)

Ganglion cells are sensitive to differential motion (sensor-jitter filter)

(based upon Baccus et al 2008)

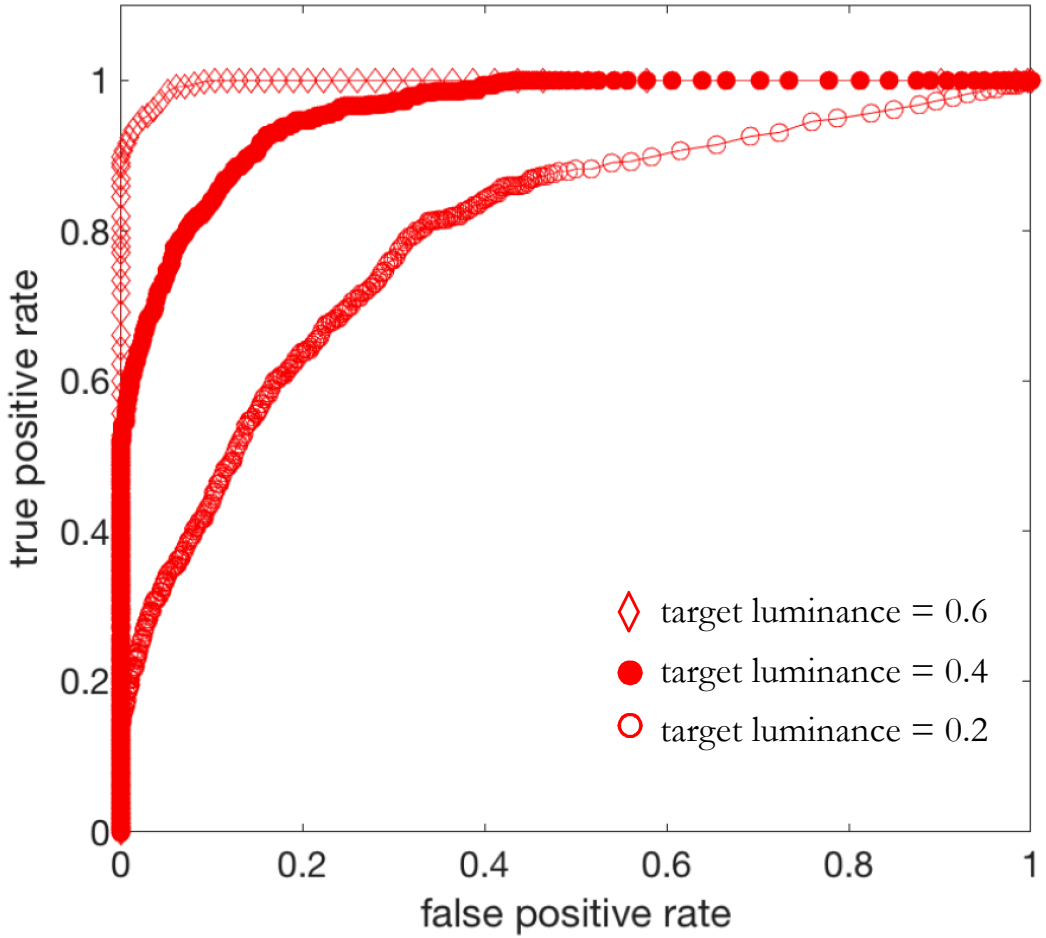
PROBLEM: Detect small moving target against white noise background

Target = small and dim, OMS detections in red

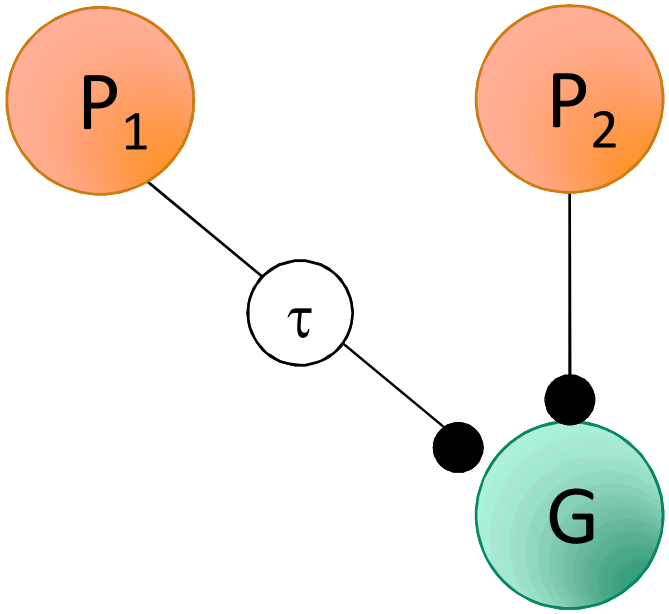


PROBLEM: Detect small moving target against white noise background

OMS model performance for varying target luminances



REICHARDT DETECTOR

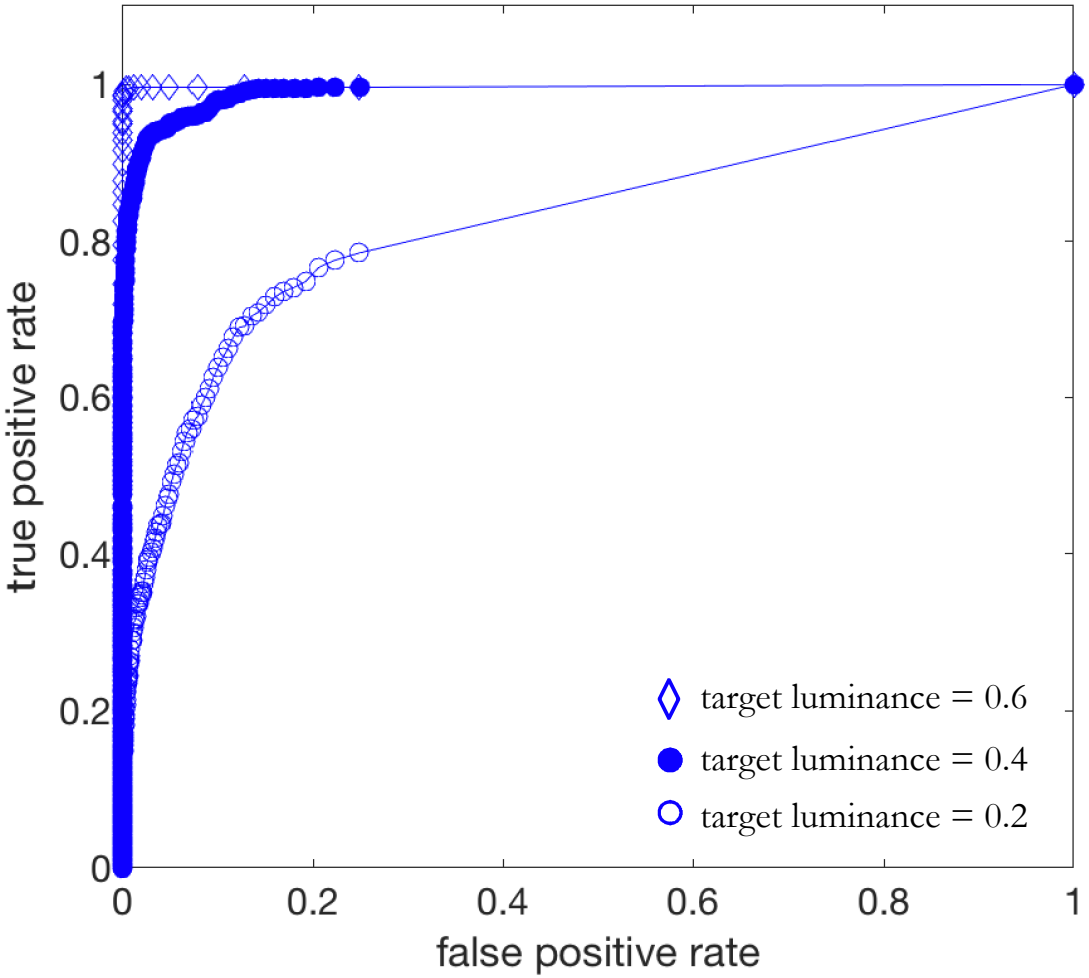


Hassenstein-Reichardt model:
direction-selective mode, true motion detector

based upon Hassenstein & Reichardt, 1956

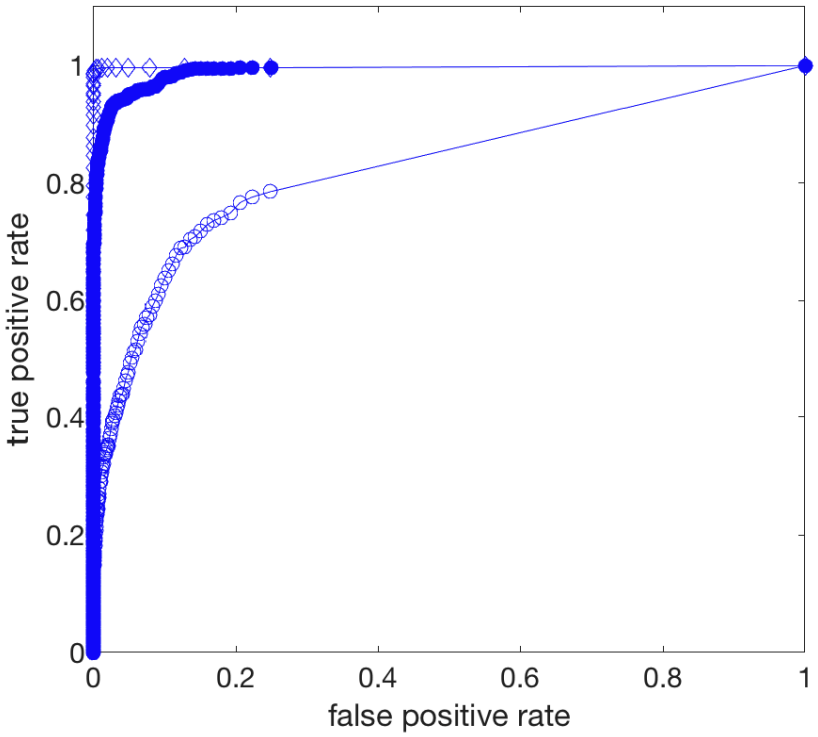
PROBLEM: Detect small moving target against white noise background

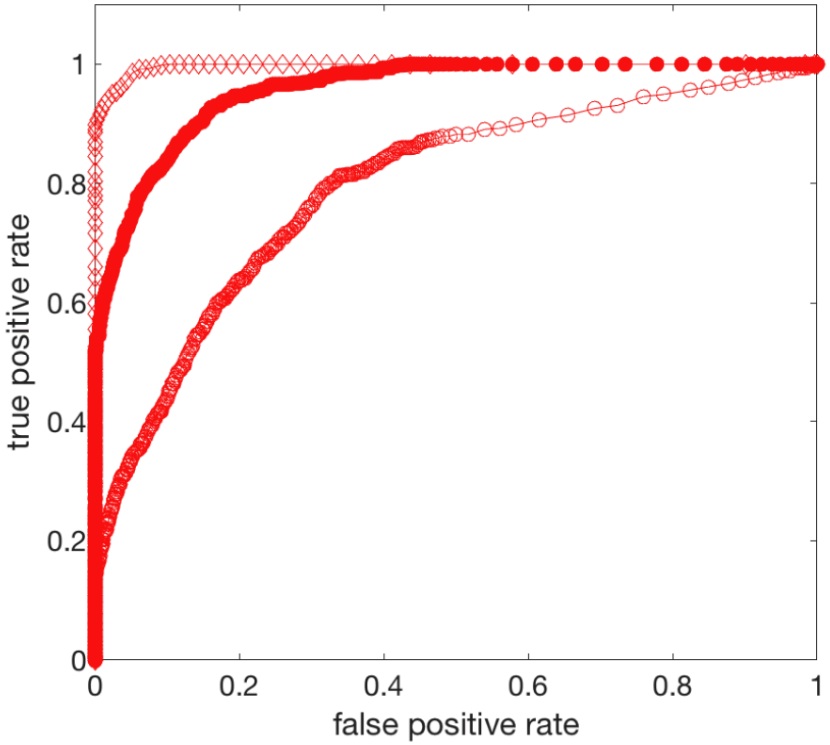
Reichardt model performance for varying target luminances



PROBLEM: Detect small moving target against white noise background

Reichardt model performs better than OMS for white noise background





◊ target luminance = 0.6
● target luminance = 0.4
○ target luminance = 0.2

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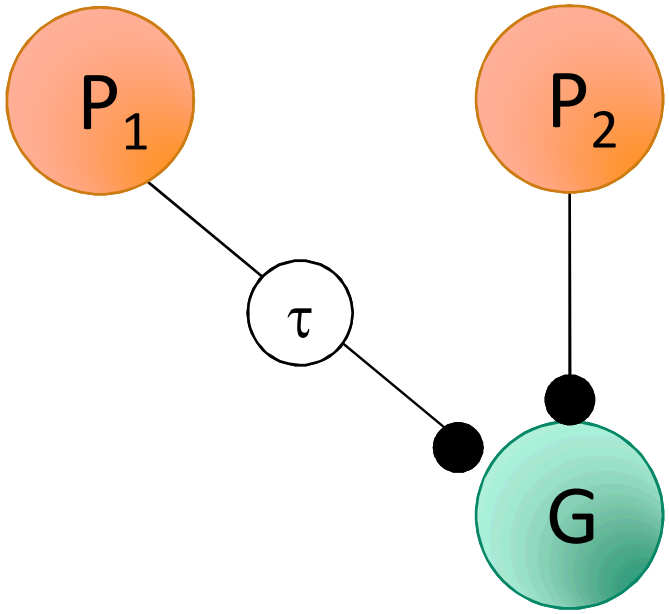
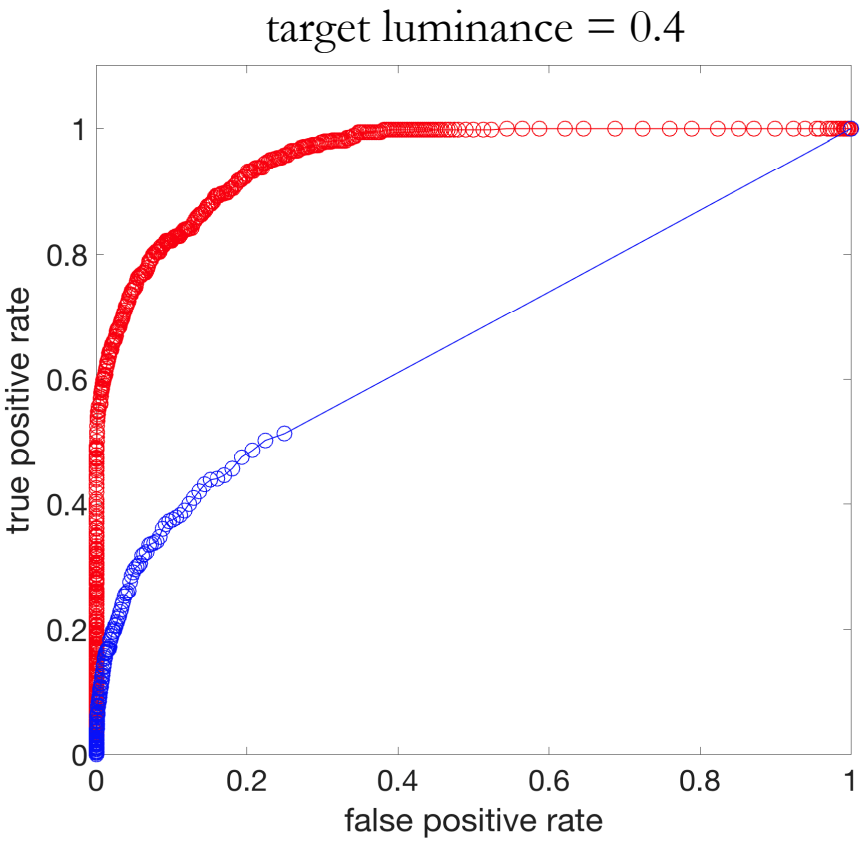
REICHARDT DETECTOR

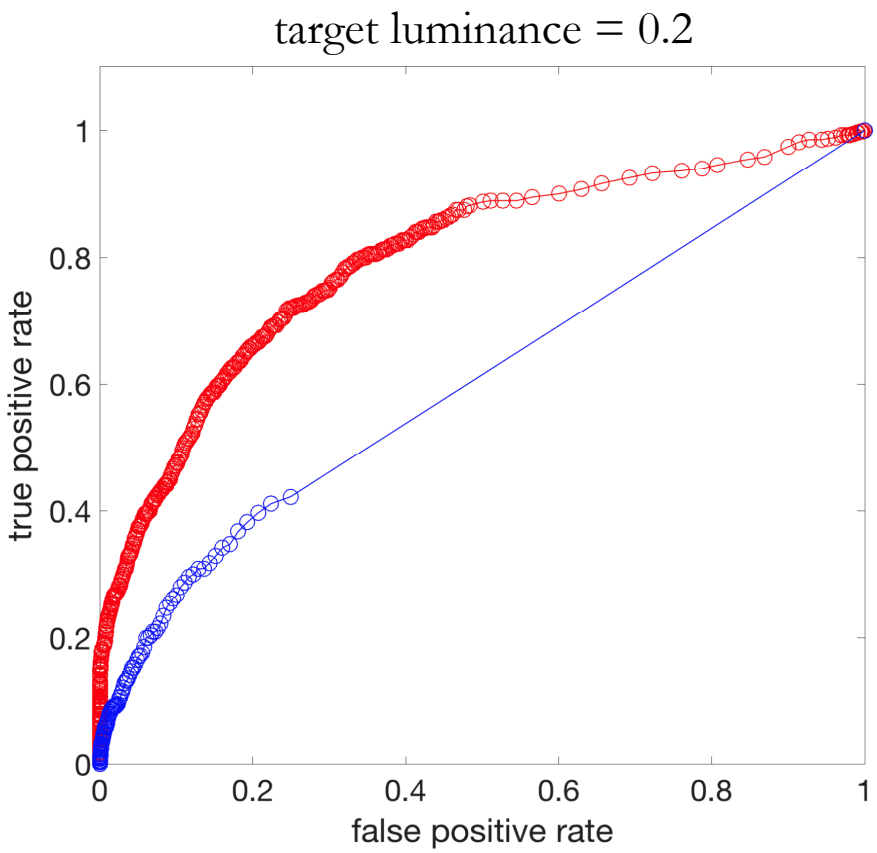


Hassenstein-Reichardt model:
direction-selective mode, true motion detector

based upon Hassenstein & Reichardt, 1956

PROBLEM: Detect small moving targets of varying speeds – target speed is doubled





OMS model

Reichardt model

COMPARISON: OMS model vs Reichardt model

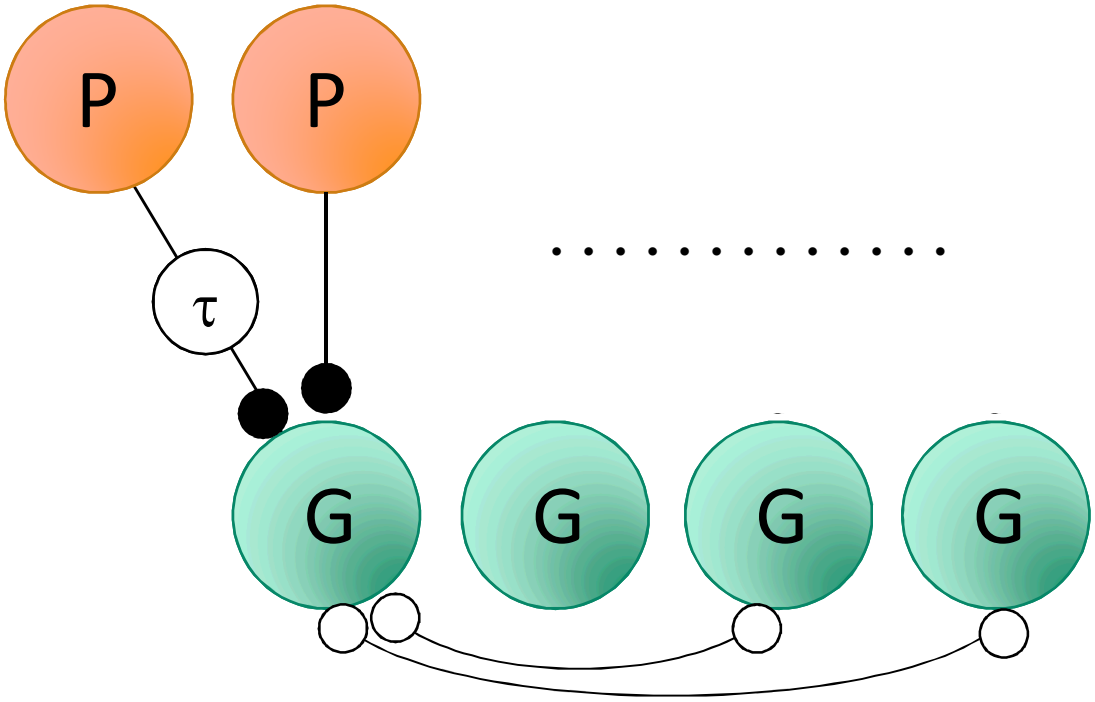
Object-motion sensitive (OMS) model

- Filters temporally-synchronized clutter signals (e.g. jitter)
- Vulnerable to continuously varying clutter (e.g. white noise)
- Insensitive to target speed

Reichardt detector model

- Detects motion in one direction
- Better performance under white noise clutter
- Vulnerable to changes in target speed

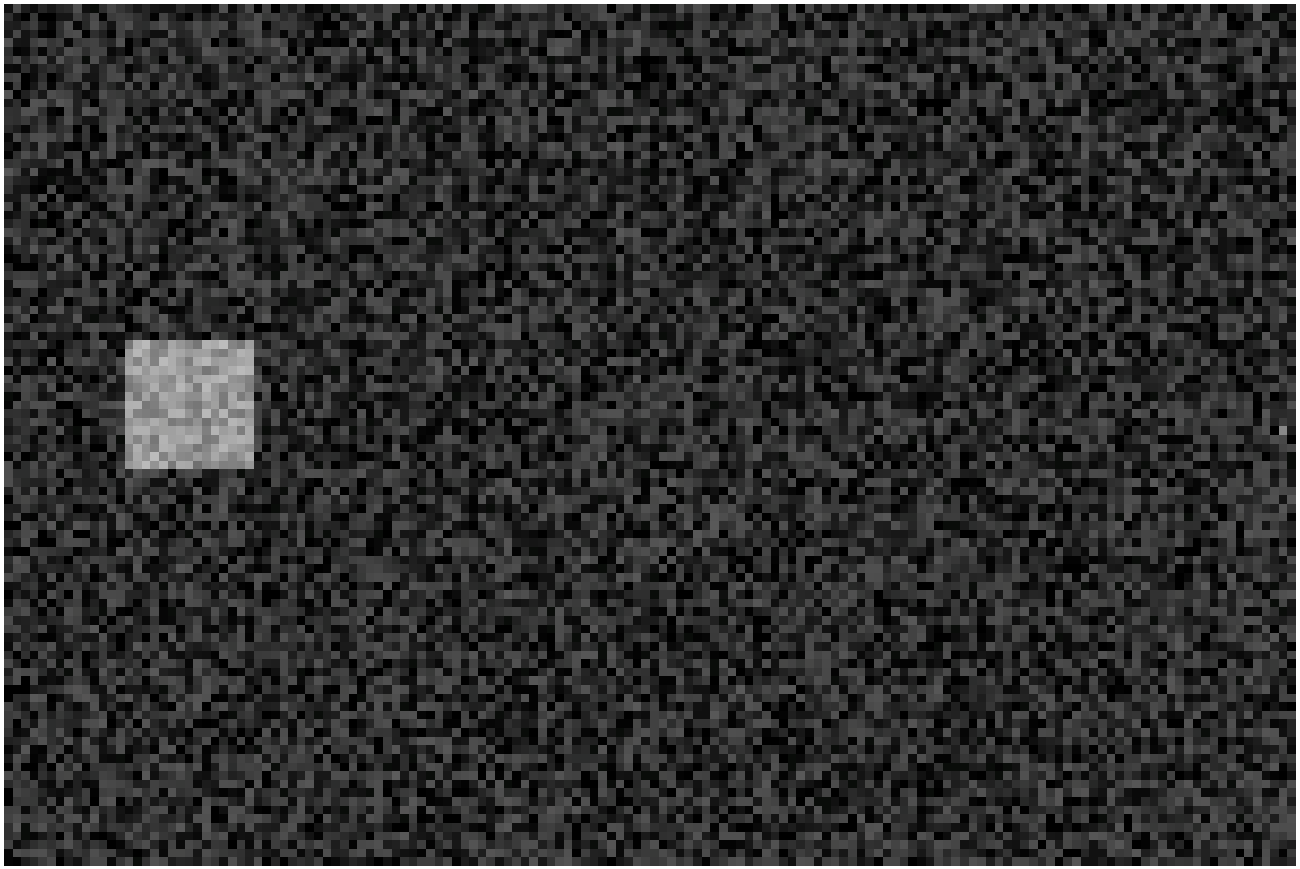
INCLUDING LATERAL INHIBITION



analagous to the W3 cell (lateral inhibition mediated by amacrine cells) – see Zhang et al 2012

SIZE-TUNING THROUGH LATERAL INHIBITION

Example stimulus: large-object clutter



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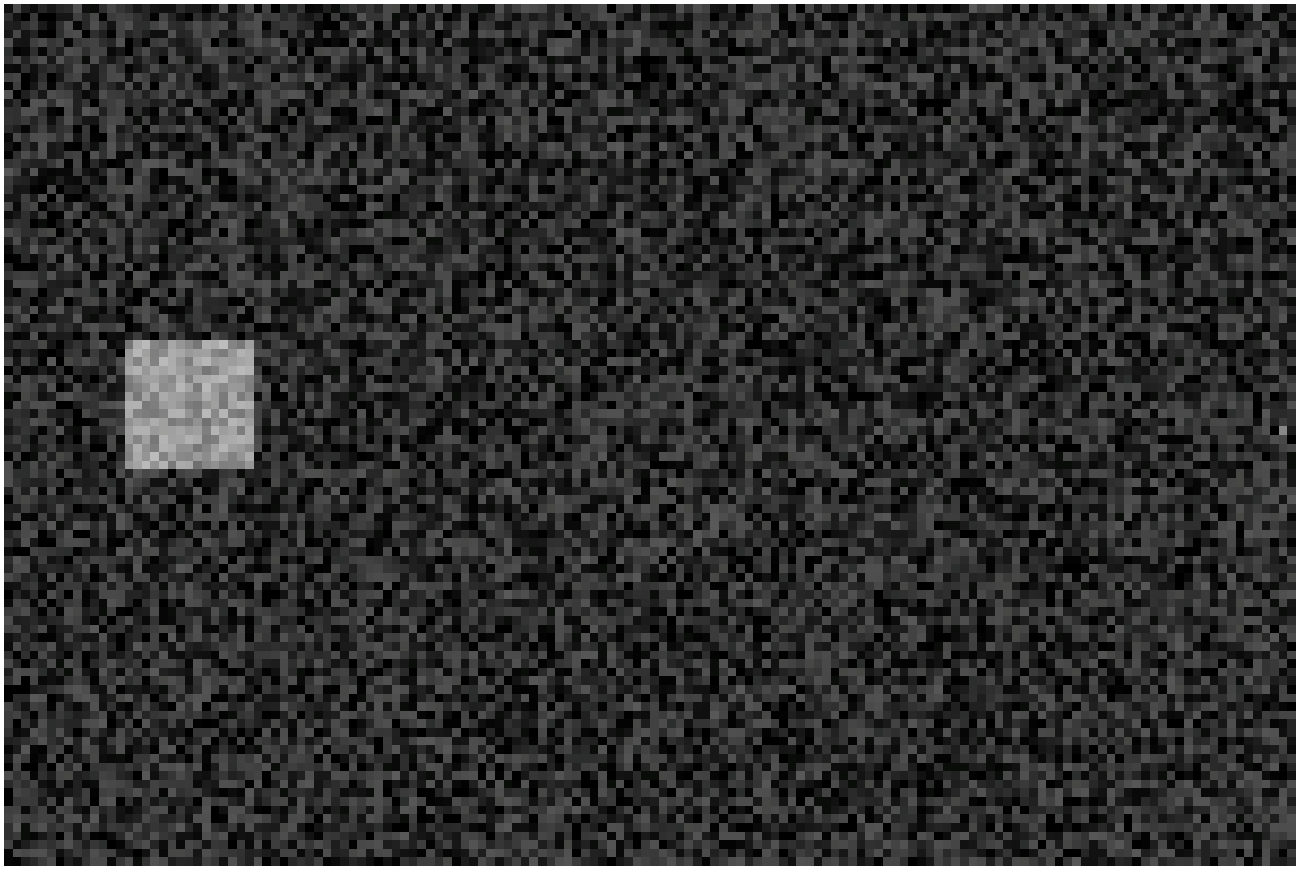
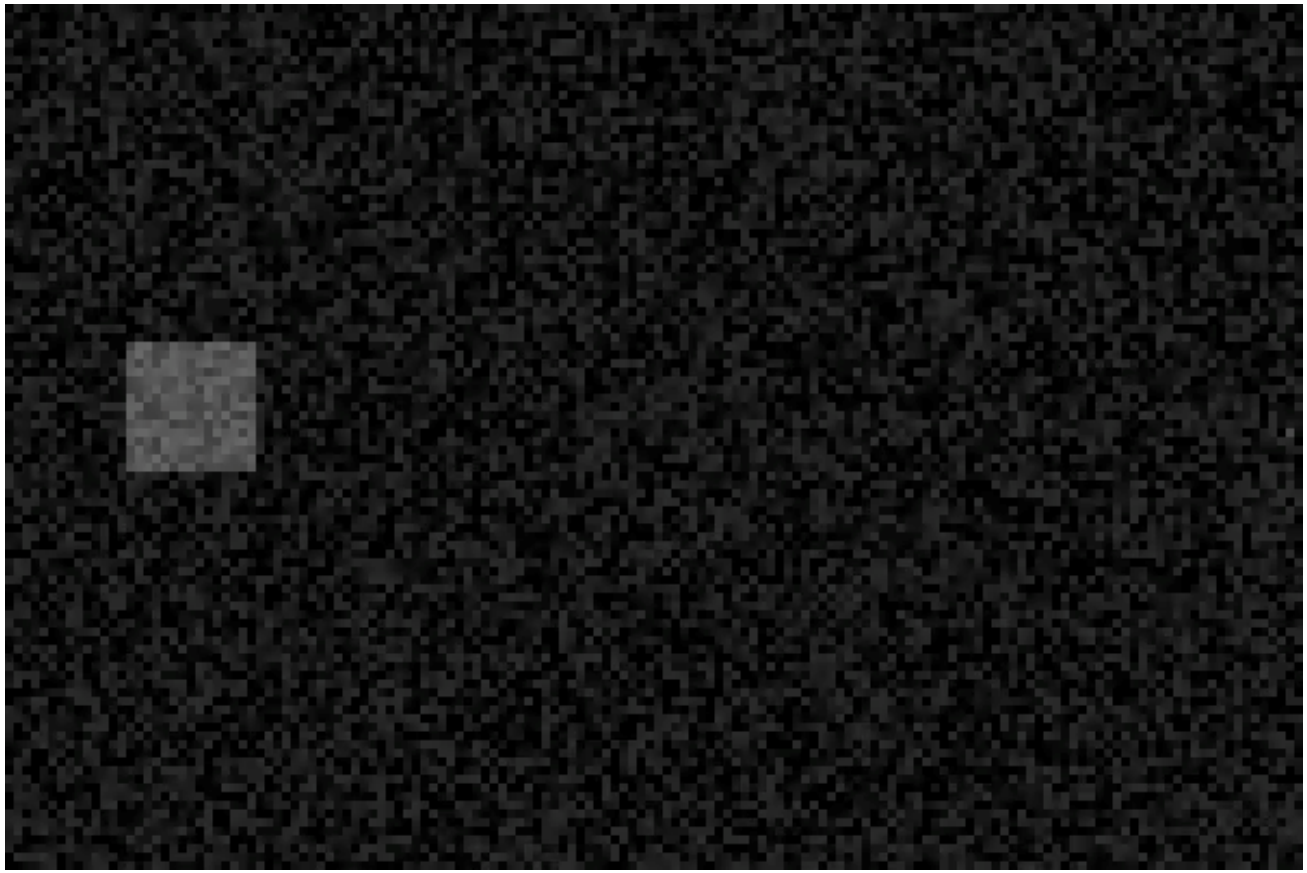


SIZE-TUNING THROUGH LATERAL INHIBITION

Reichardt-detector responses with large-object clutter



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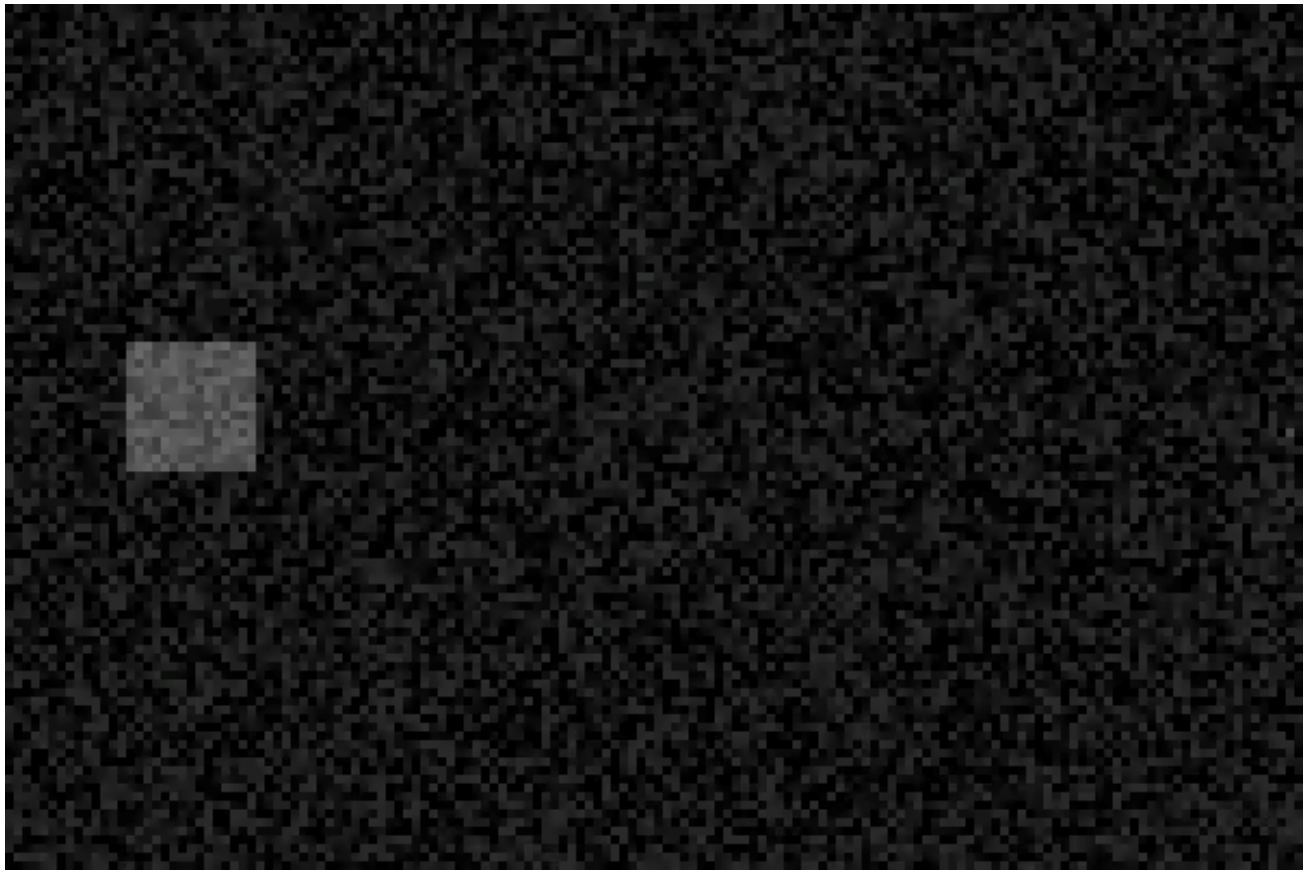
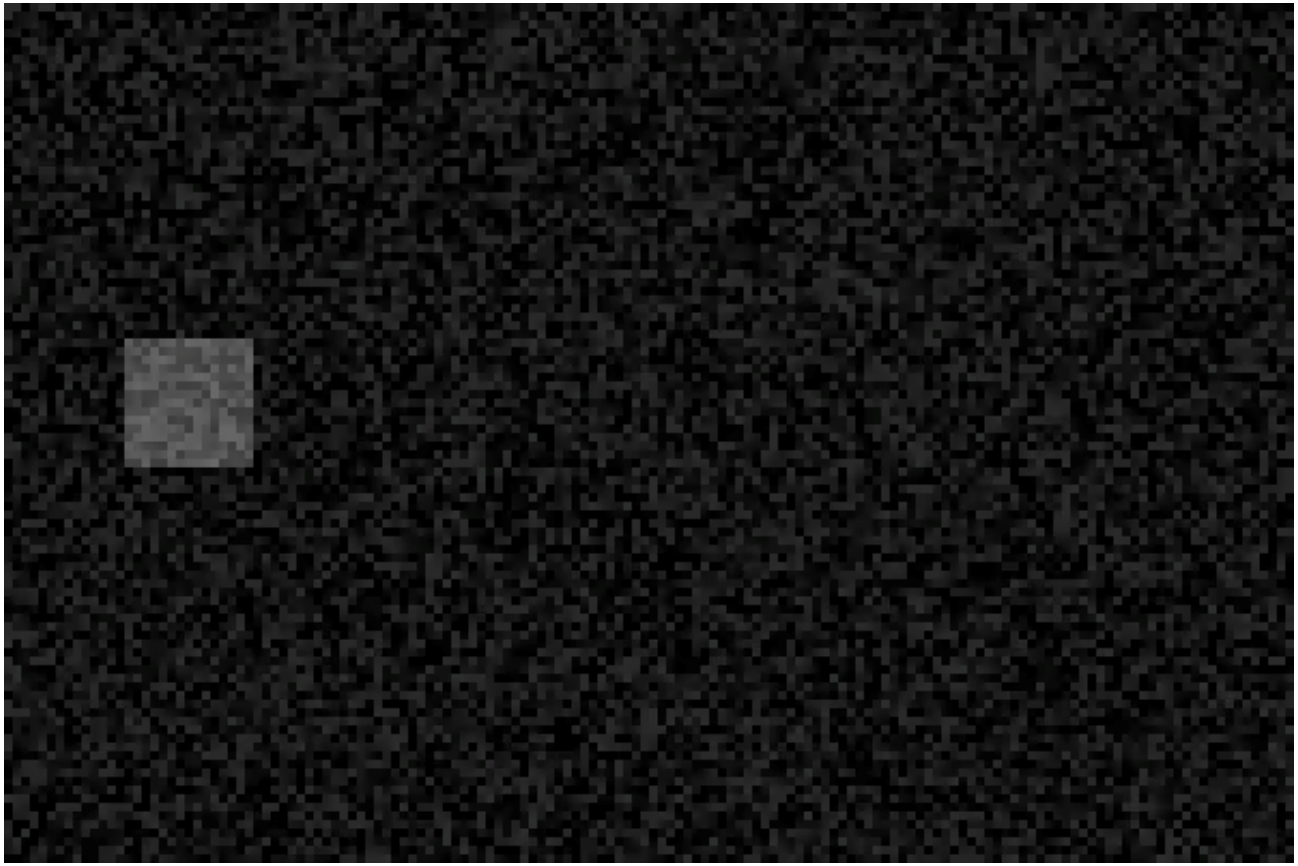


SIZE-TUNING THROUGH LATERAL INHIBITION

Reichardt-detector responses (lateral inhibition included)
large-object clutter



SIZE-TUNING THROUGH LATERAL INHIBITION

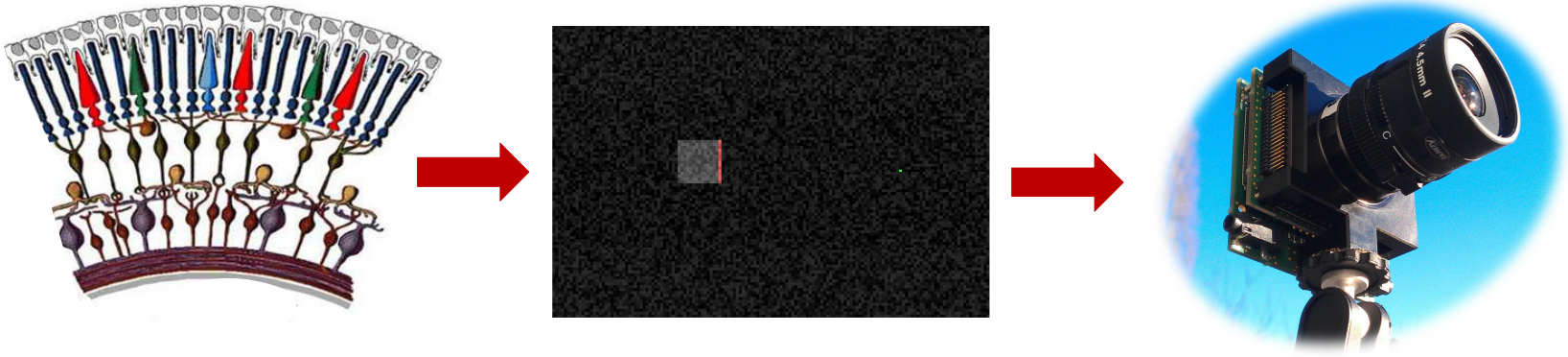
Reichardt-detector responses (lateral inhibition included)
large-object clutter with white noise

SIZE-TUNING THROUGH LATERAL INHIBITION

Reichardt-detector responses ONLY (lateral inhibition included)
large-object clutter with white noise

SUMMARY

How does the retinal circuit produce interesting computation?



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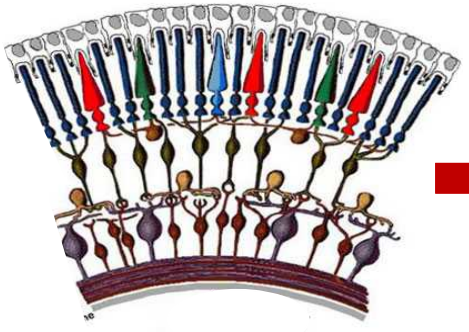

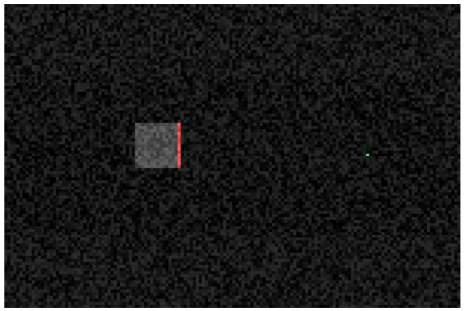

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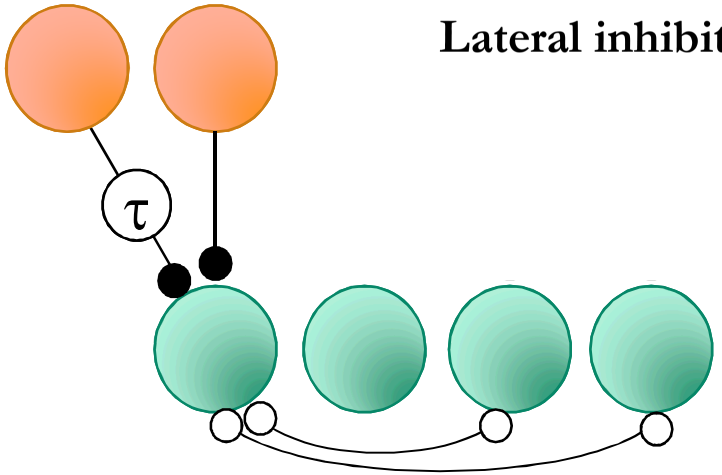

Lateral inhibition can underlie target size-tuning

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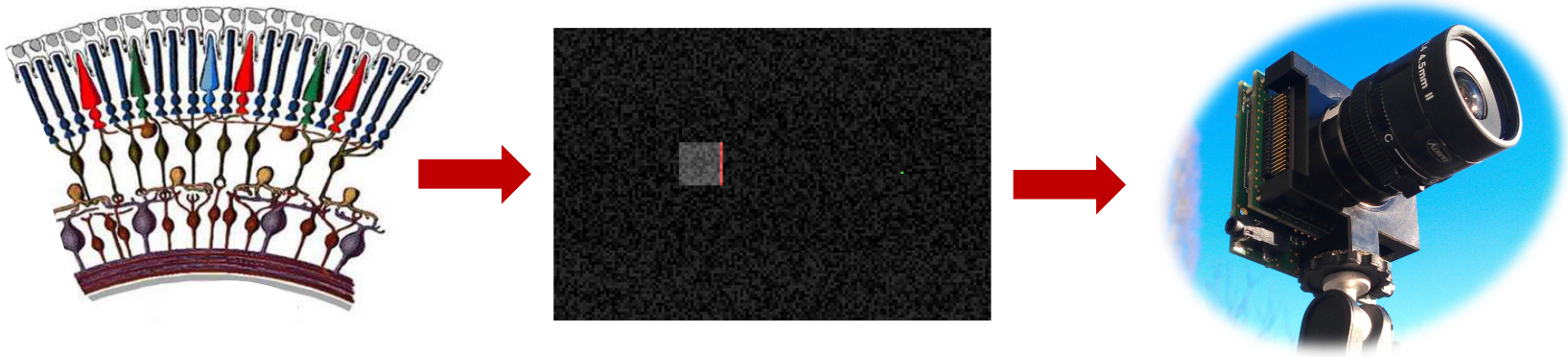

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