Drift Gain: Modeling Peripheral Retina

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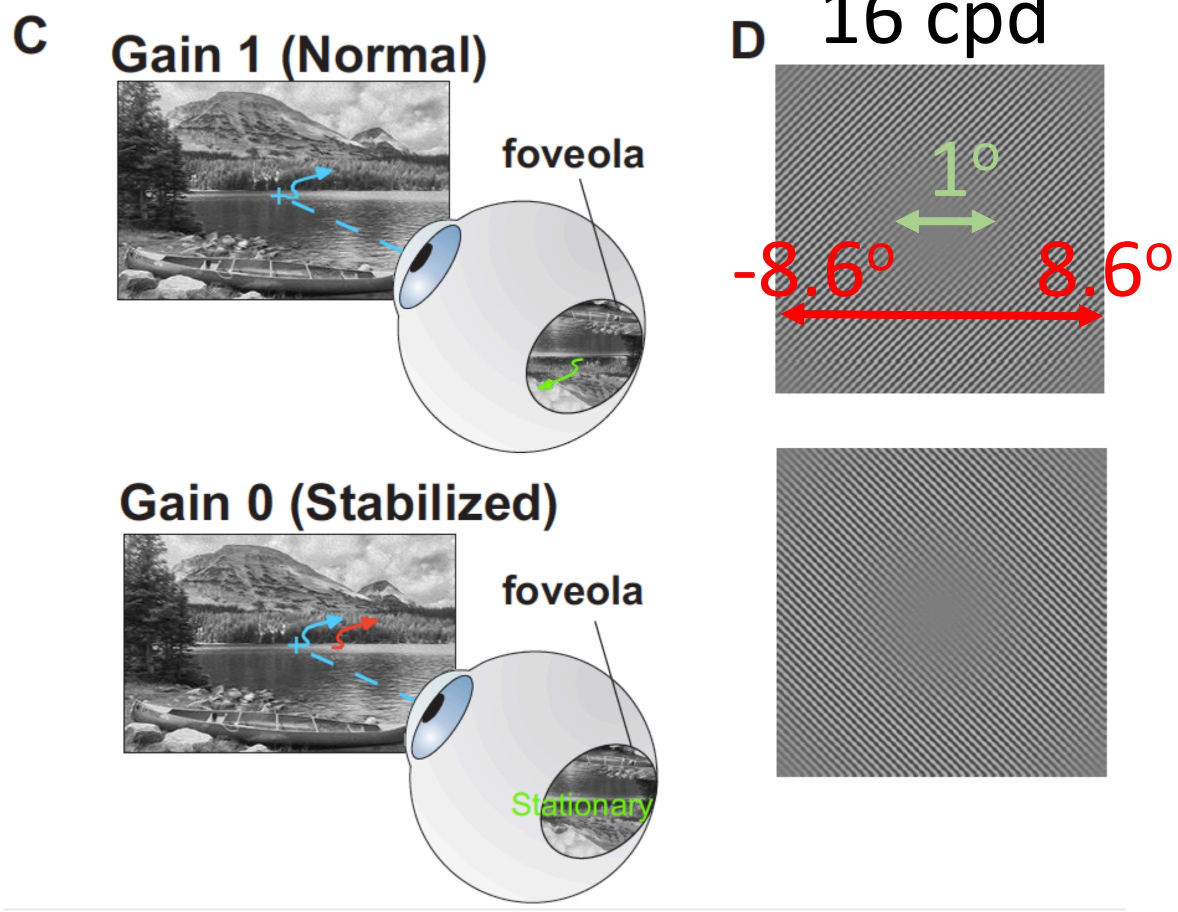
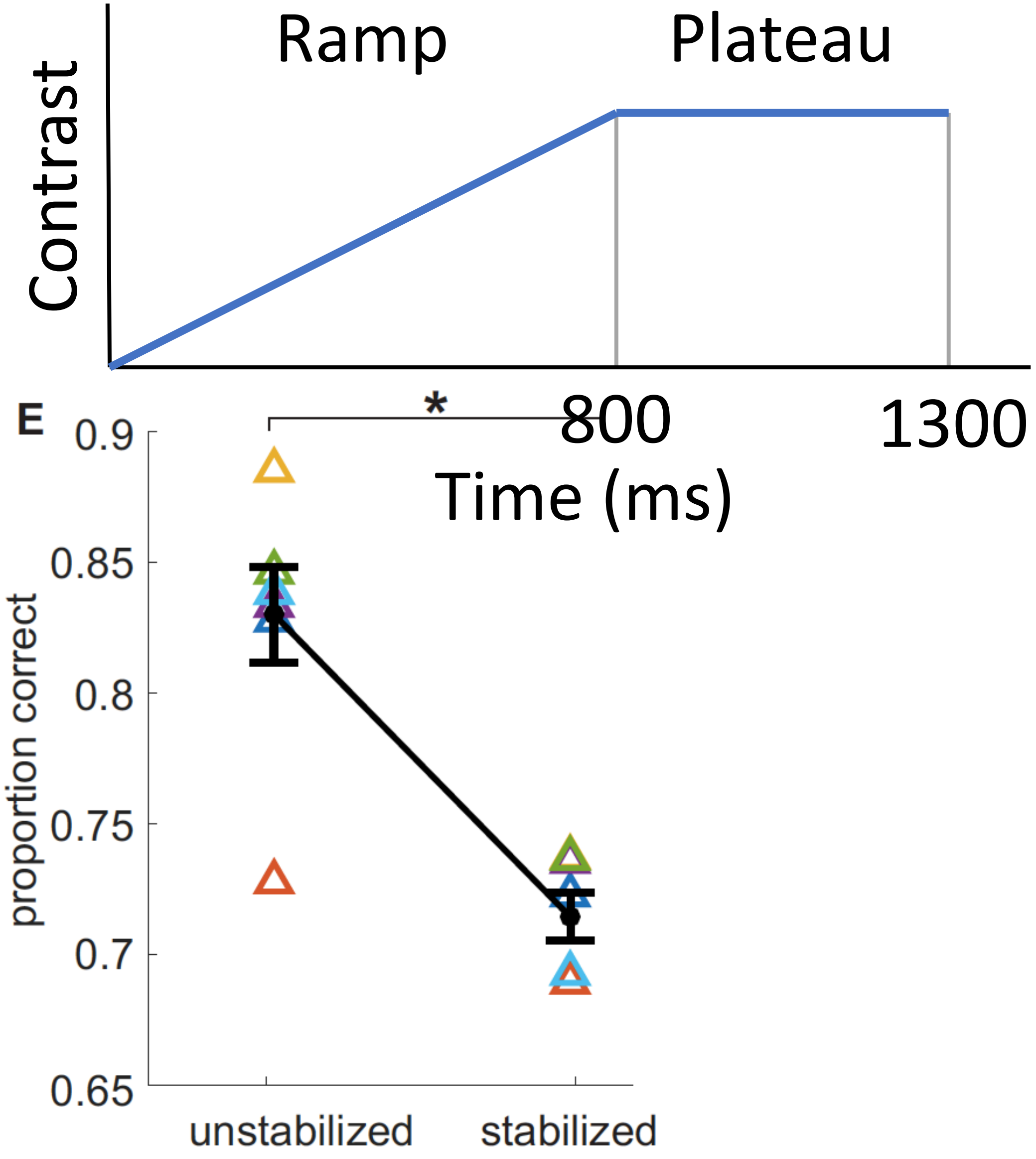
Do drift modulations matter for peripheral acuity?





Spatial Resolution by Eccentricity

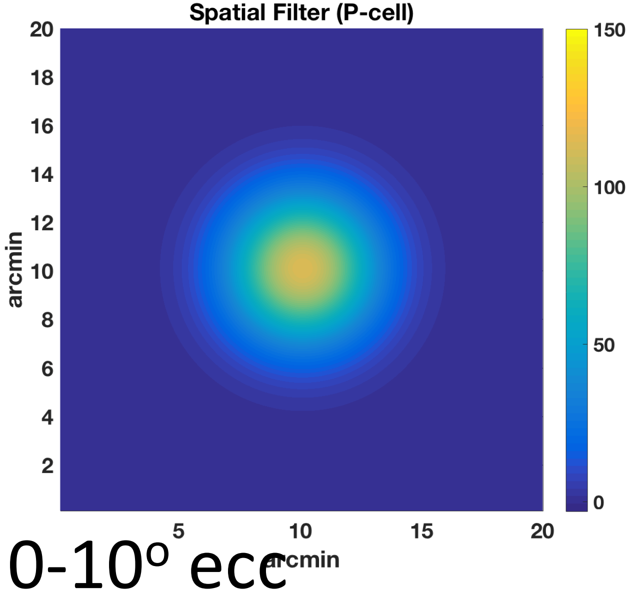
- Optics of the eye and cone density limit visual acuity at eccentricities up to 2-degrees (Green, 1970; Rossi & Roorda, 2010)
- Beyond this retinal ganglion cell (RGC) spacing is believed to determine visual resolution (Thibos et al, 1987; Merigan & Katz, 1990; Dacey, 1993; Rossi & Roorda, 2010)
  - Specifically the spacing between off P-cells
  - RGC convey information to higher visual areas

Retinal Ganglion Cells

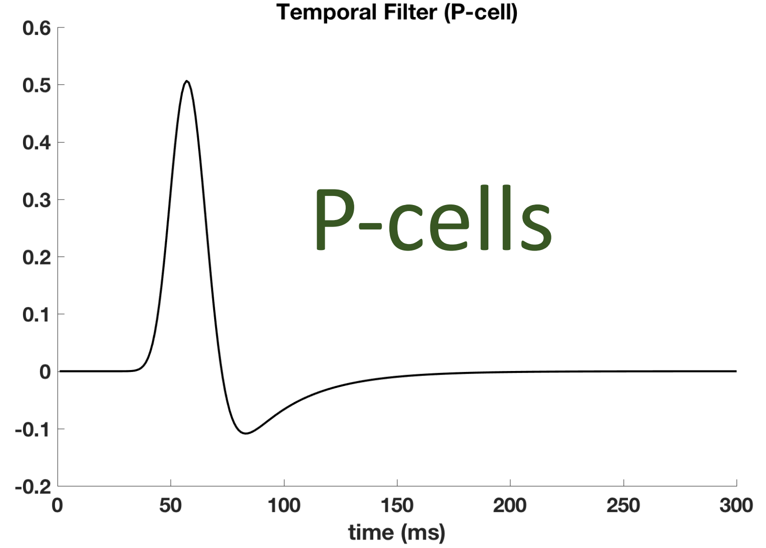
- Two main varieties: P-cells and M-cells which project to the parvocellular and magnocellular layers of LGN respectively
- Across the entire retina: 80% of RGC are P-cells and 10% are M-cells
  - Percentage of RGC that are P-cells falls from 95% to 45% between 12^o and 25^o eccentricity (human - Dacey, 1993)
  - Proportion of M-cells increases with eccentricity (macaque - Silveira & Perry, 1991)
- coupled ON- and OFF-pathways
  - ON and OFF P-cells have 1:1 ratio in central retina (up to 5^o)
  - At 25^o the ratio of ON to OFF is 1:1.7 (Dacey, 1993)
  - ON cells have larger RF; ON cells have faster temporal dynamics (Chichilnisky & Kalmar, 2002)

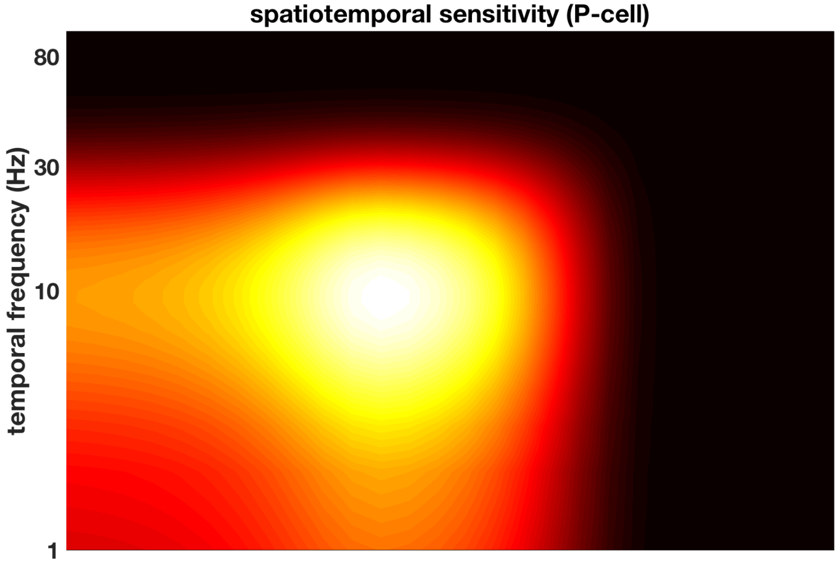
RGC Spatiotemporal characteristics

5-10° ecc

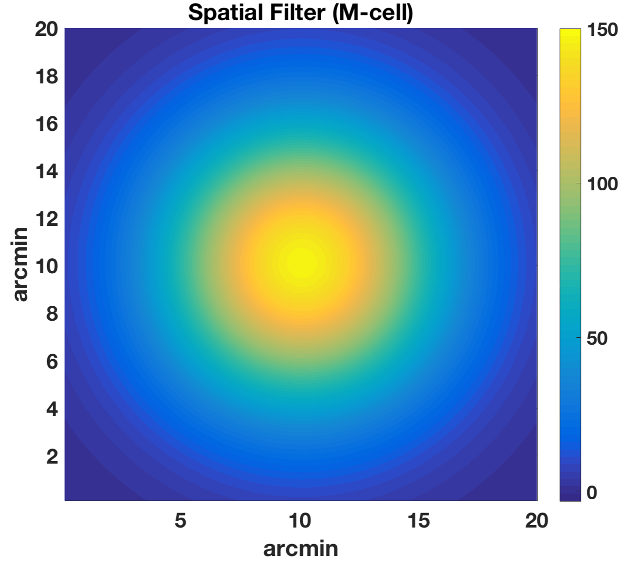


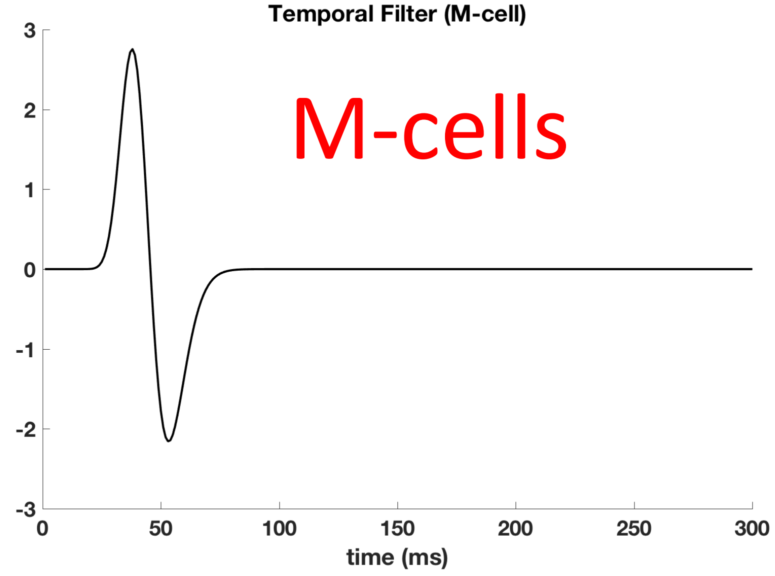
2.5-4° ecc

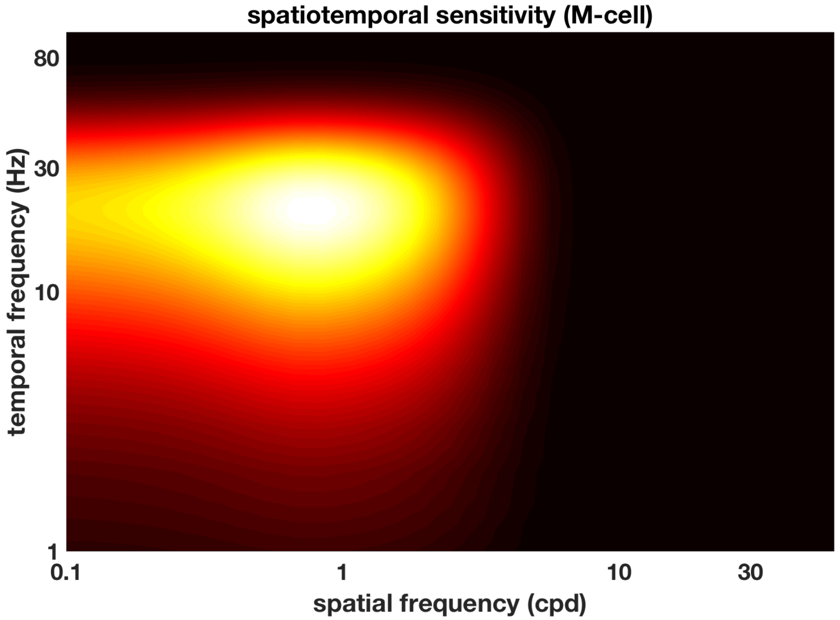




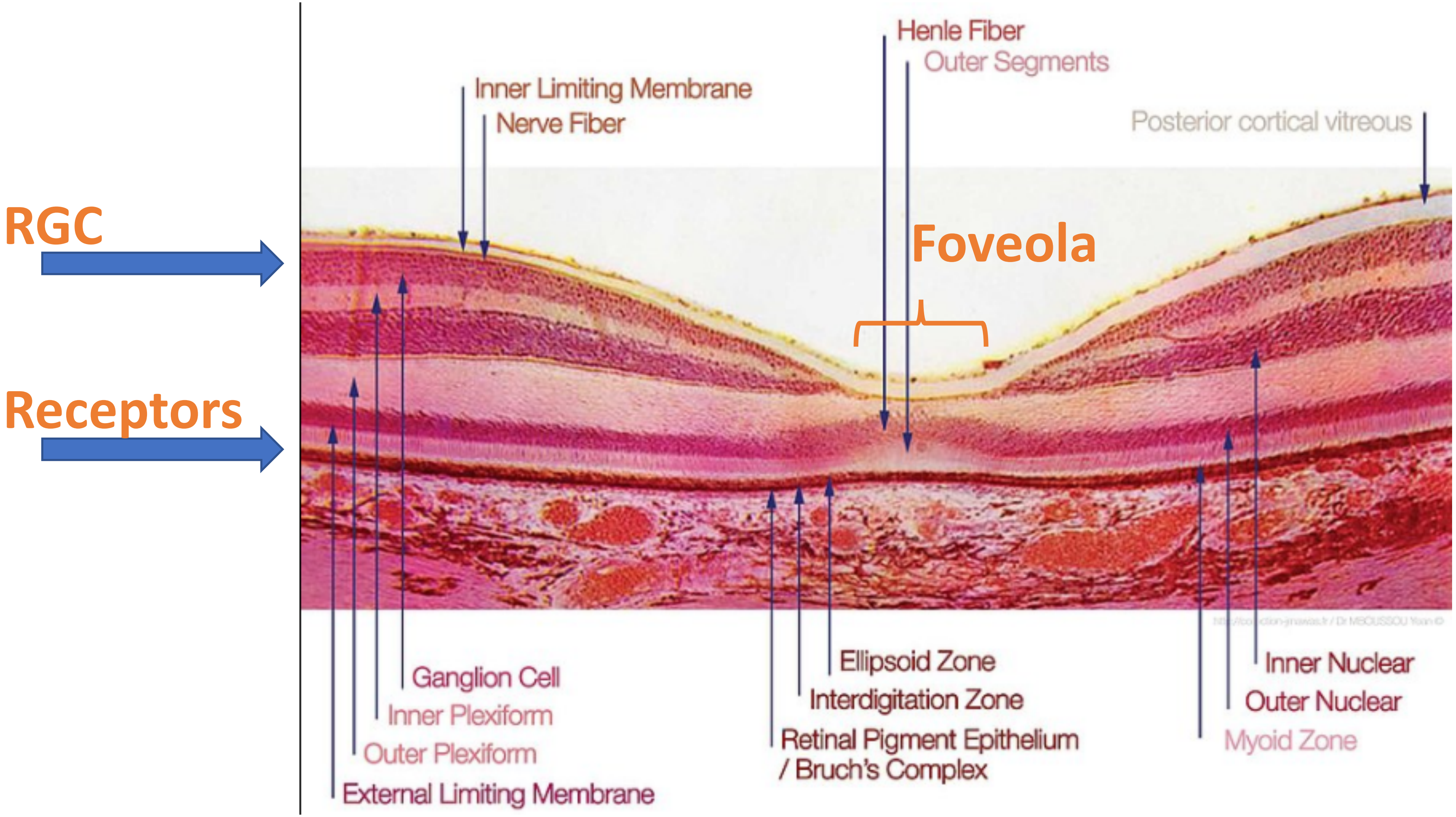
0-10° ecc





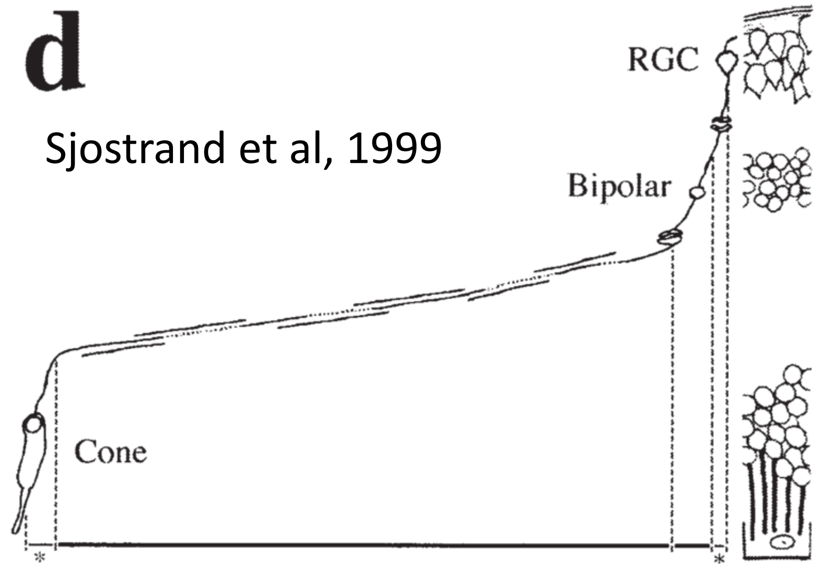


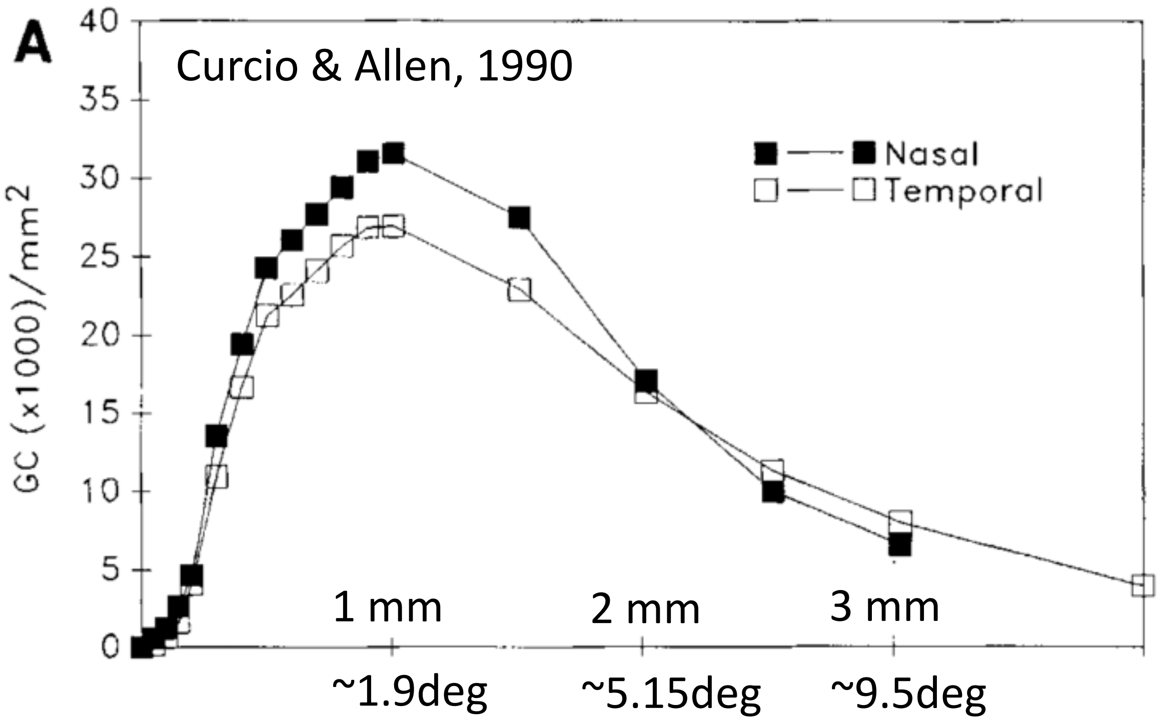
RGC lateral displacement



RGC displacement

- RGC are laterally displaced from their corresponding cones and receptive fields up to 15^o
- Displacement is well mapped and varies with eccentricity (Drasdo et al, 2007; Sjostrand et al, 1999)





RGC Mosaic at 5^o eccentricity

Study	Cell type	Reported density (2D)
Curcio & Allen, 1990	**Human** – all RGC	14×10^3 / mm^2
Drasdo et al, 2007	**Human** – Pcells (model)	10×10^3 / mm^2
Dacey, 1993	**Human** - Pcells	12×10^3 / mm^2
C&A – Dacey	**Human** – Mcells estimation	1×10^3 / mm^2 2×10^3 / mm^2
Perry & Cowey, 1985	**Macaque** – all RGC	31×10^3 / mm^2
Perry & Cowey, 1985	**Macaque** – Pcells	1.5×10^3 / deg^2 ~31×10^3 / mm^2
Perry & Cowey, 1985	**Macaque** – Mcells	175/ deg^2 ~3.6×10^3/ mm^2
Silveira & Perry, 1991	**Macaque** - Mcells	2.5×10^3 / mm^2

Model of RGC density by eccentricity based on measured visual acuity, optical quality, RGC:cone ratio,…

P-cells identified by size of soma

Difference of densities of all RGC from Curcio & Allen, 1990 and P-cells from Dacey, 1993

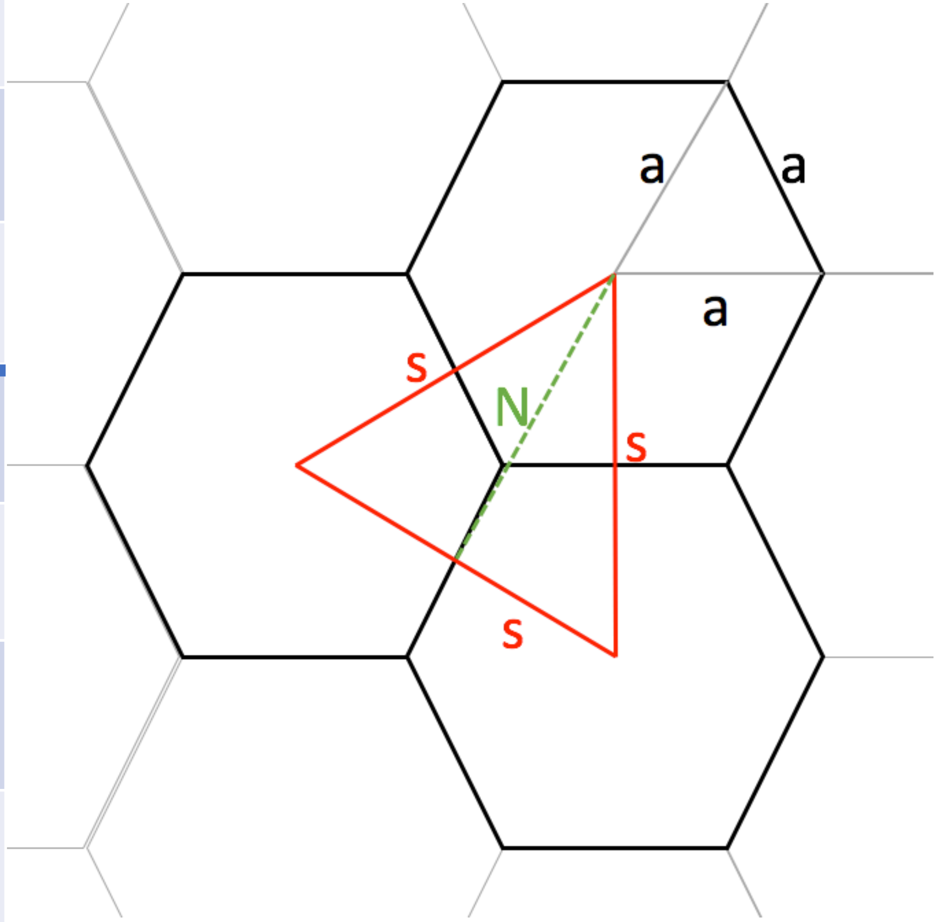
Macaques may have more dense RGC mosaics, possibly to make for their smaller eyes

RGC Mosaic at 5° eccentricity

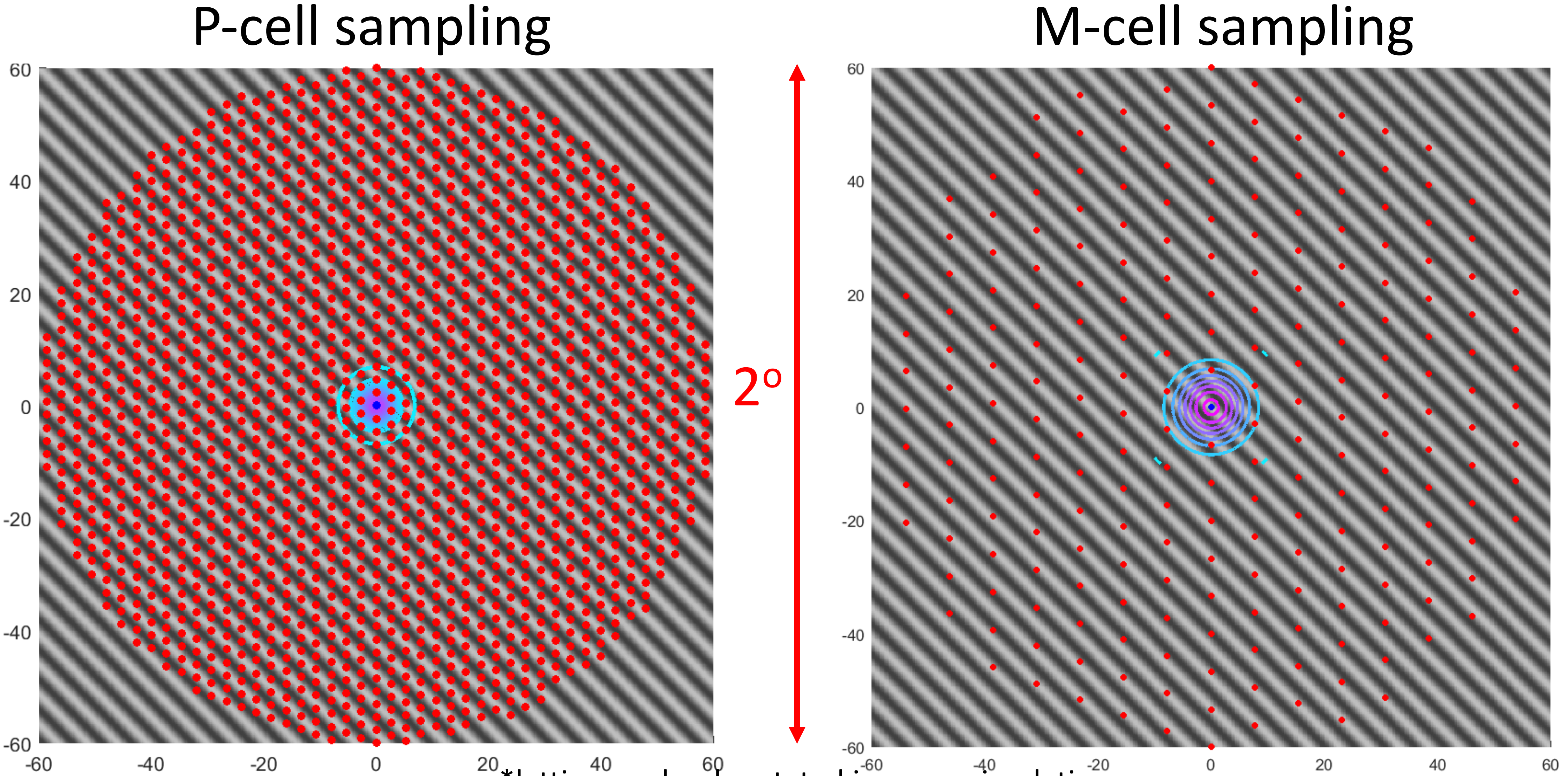
Study	Cell type	Reported density (2D)	Spacing rows(N)	Sampling frequency
Curcio & Allen, 1990	**Human** – all RGC	14×10^3 / mm^2	2.0’	29 cpd
Drasdo et al, 2007	**Human** – Pcells (model)	10×10^3 / mm^2	2.4’	25 cpd
Dacey, 1993	**Human** - Pcells	12×10^3 / mm^2	2.2’	27 cpd
C&A – Dacey	**Human** – Mcells estimation	1×10^3 / mm^2 2×10^3 / mm^2	7.6’ 5.4’	9 cpd 11 cpd
Perry & Cowey, 1985	**Macaque** – all RGC	31×10^3 / mm^2	2.0’	29 cpd
Perry & Cowey, 1985	**Macaque** – Pcells	1.5×10^3 / deg^2 ~31×10^3 / mm^2	2.0’	29 cpd
Perry & Cowey, 1985	**Macaque** – Mcells	175/ deg^2 ~3.6×10^3/ mm^2	6.0’	10 cpd
Silveira & Perry, 1991	**Macaque** - Mcells	2.5×10^3 / mm^2	7.2’	8 cpd

$$N = \sqrt{\frac{\sqrt{3}}{2D}}$$

D is density of OFF mosaic



Sampling of Retinal Image by RGC

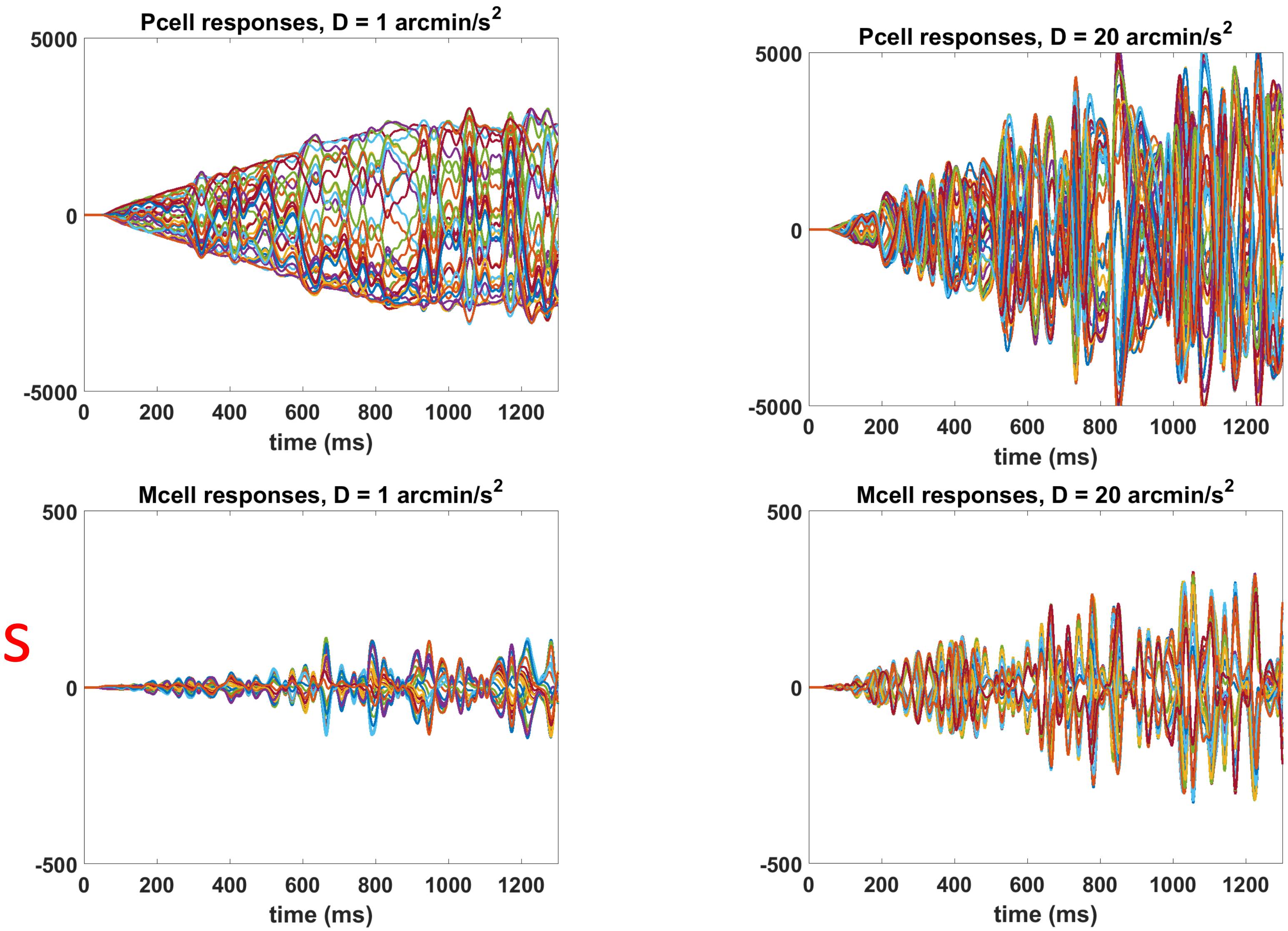


*lattice randomly rotated in every simulation

RGC Responses with retinal image motion

P-cells

M-cells



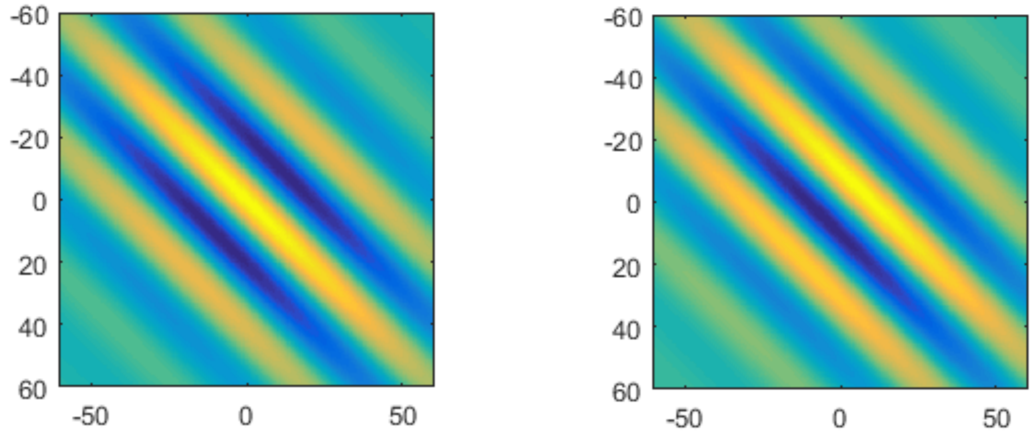
“V1” cells to detect orientation

2 simple cells for each orientation:

- Gabor receptive fields differ in phase (quarter-cycle phase step)
- Full-wave rectification accounts for ON/OFF RF

1 complex cell for each orientation (phase invariant)

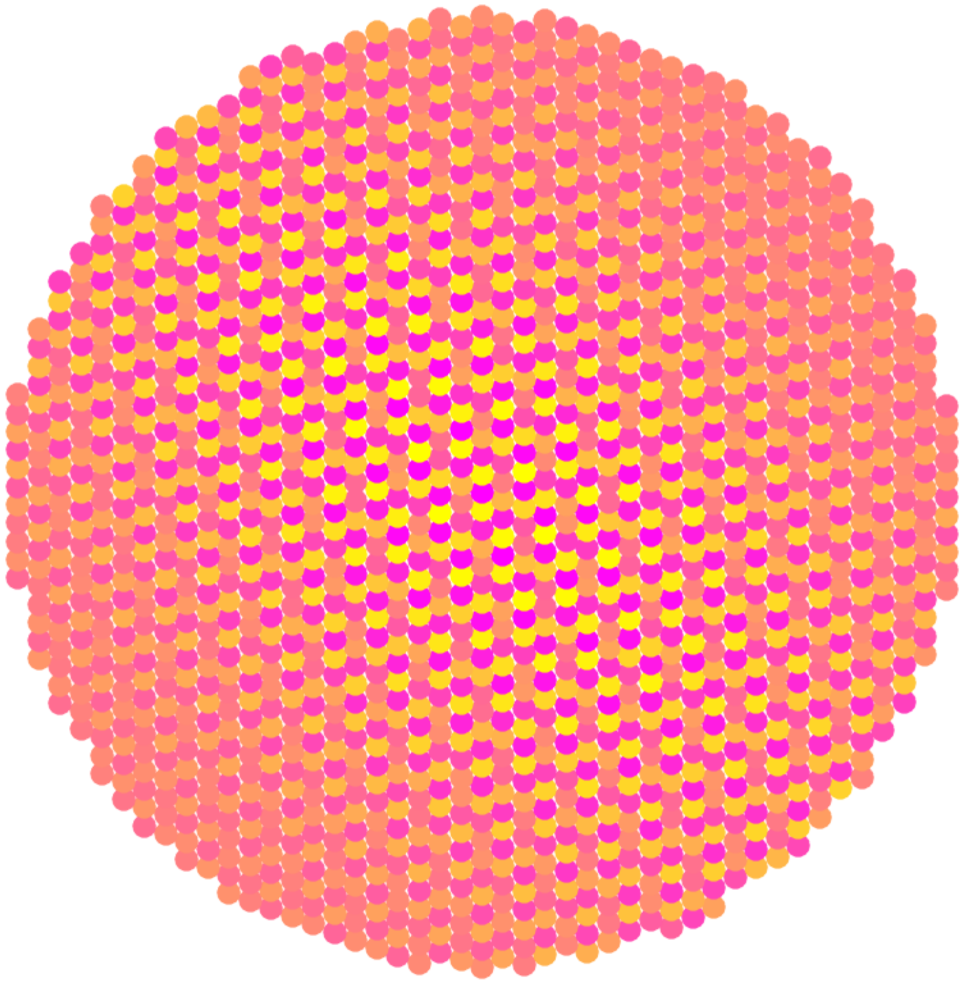
- Sum responses of simple cells



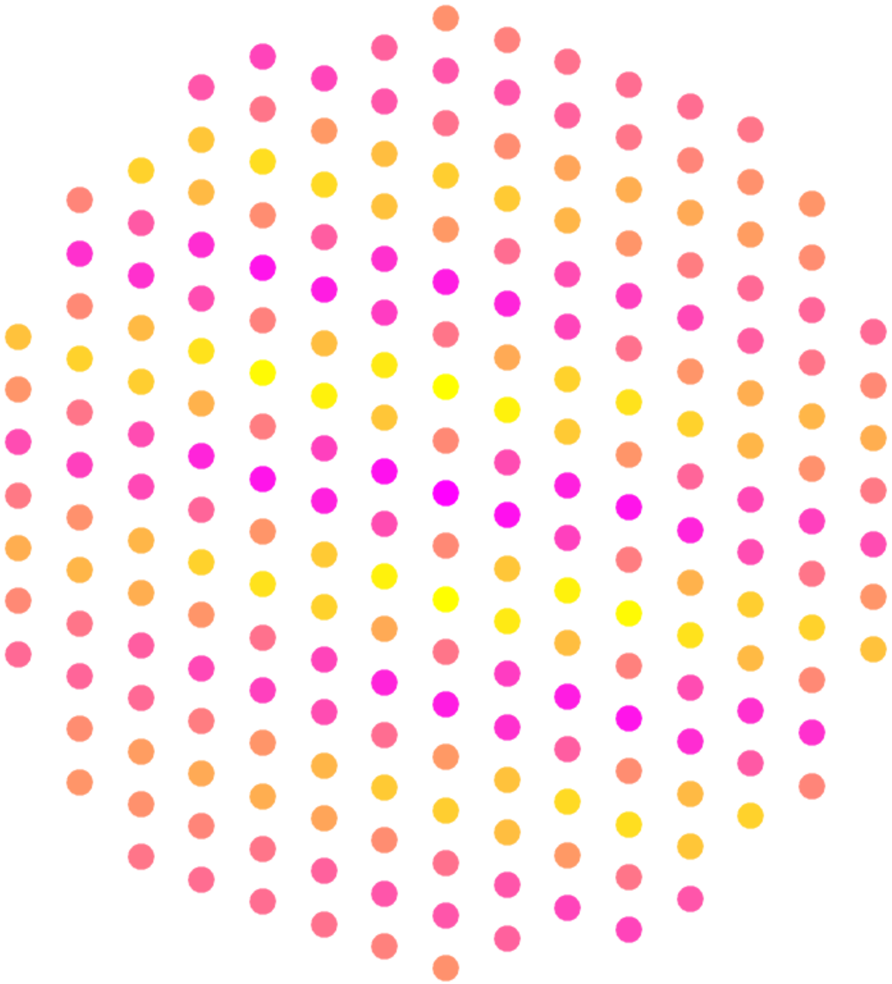
Example simple cells RF for 2cpd

V1 simple cell – weights on RGC

P-cells



M-cells

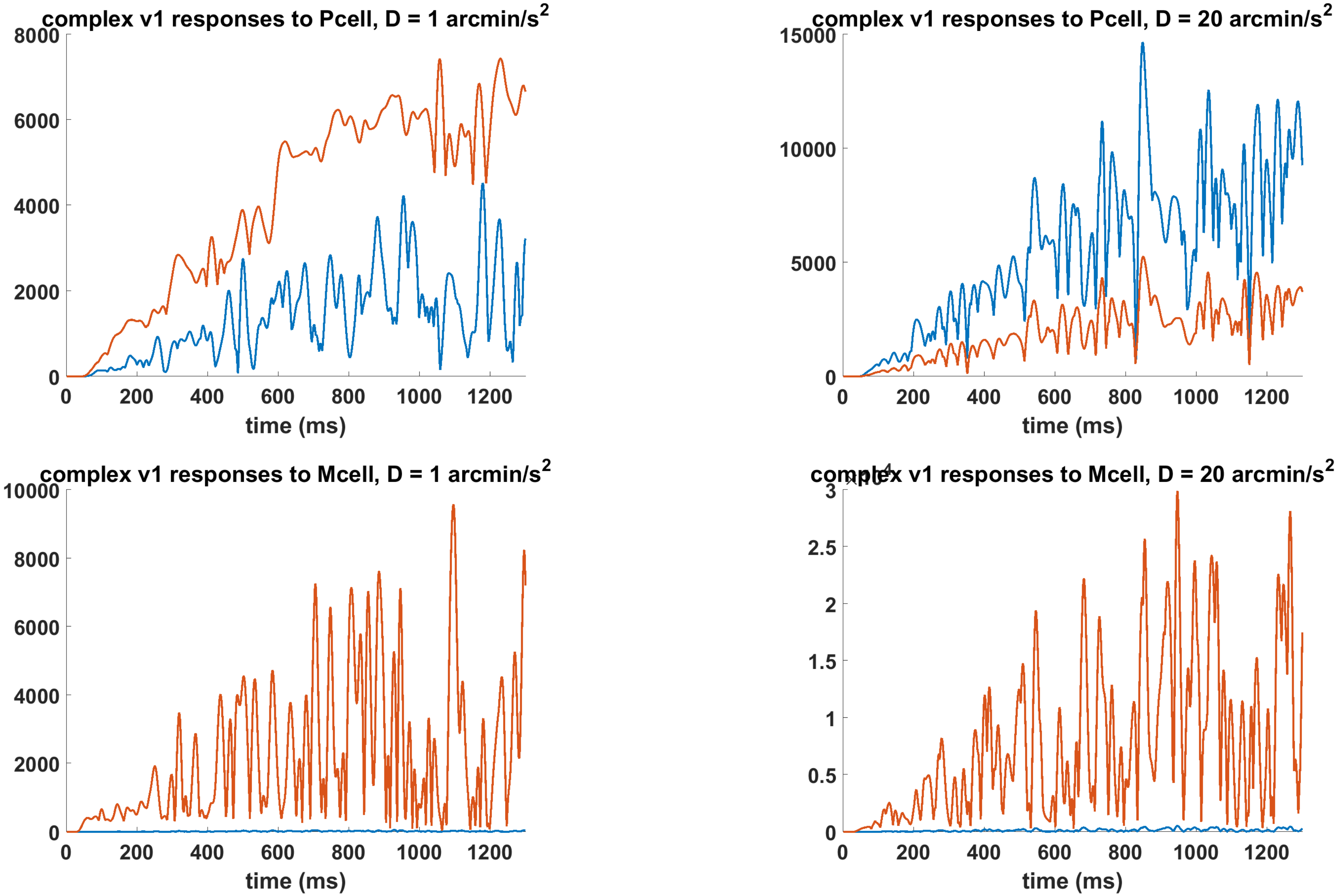


*lattice randomly rotated in every simulation

“V1” complex cell responses

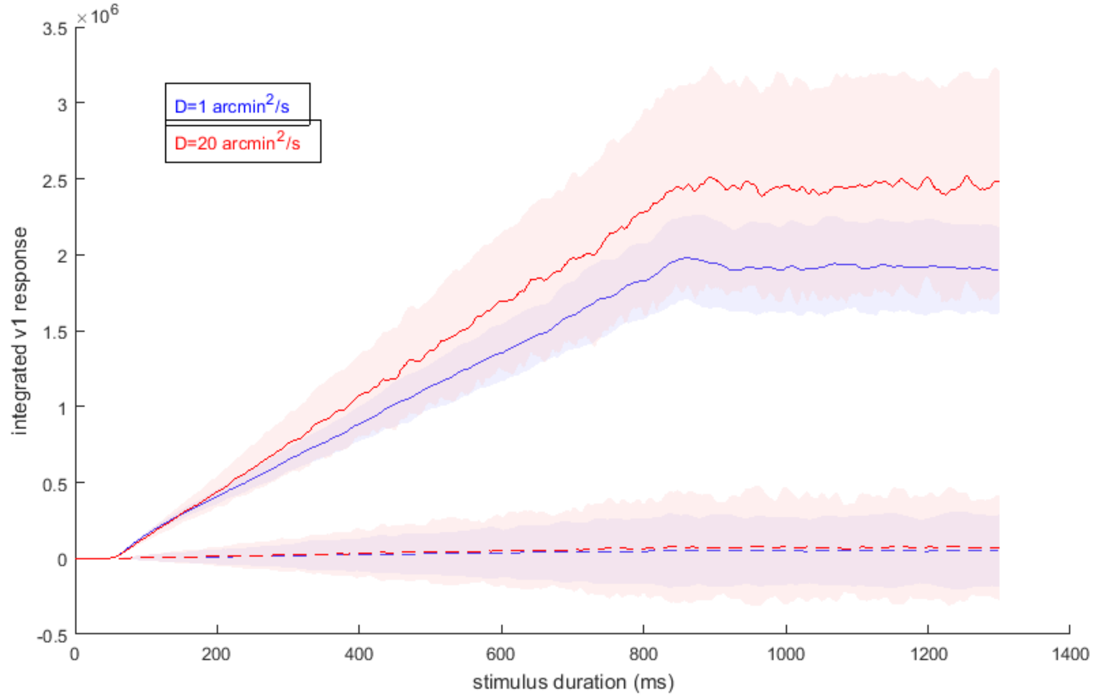
P-cells

M-cells

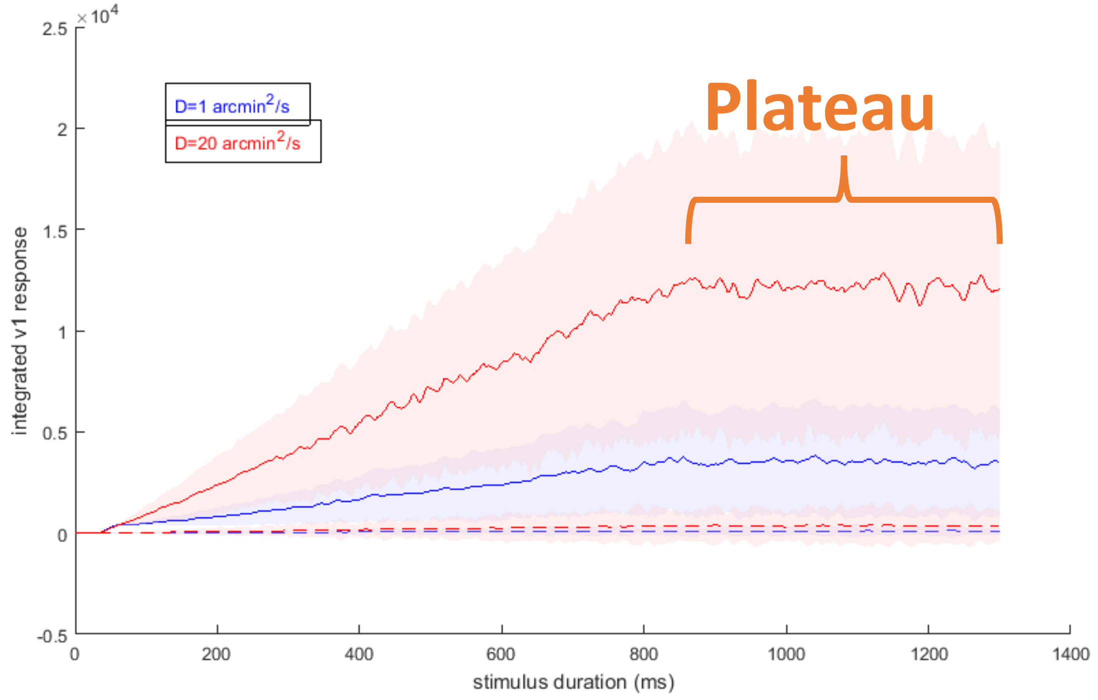


500 simulations: V1 Responses

P-cells



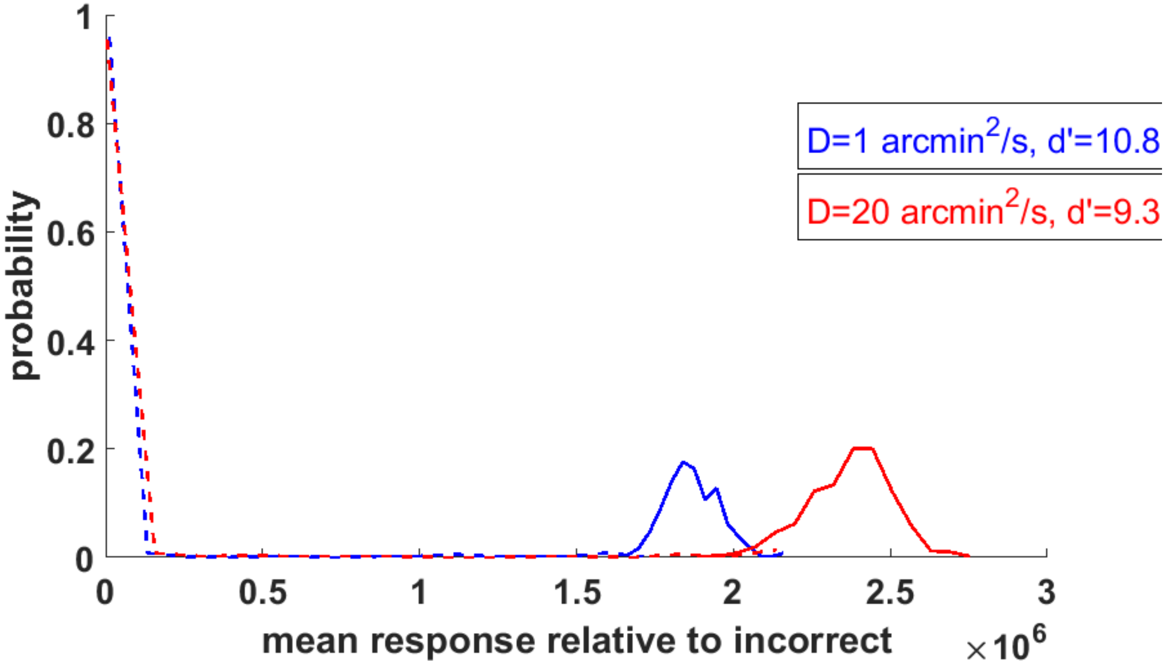
M-cells



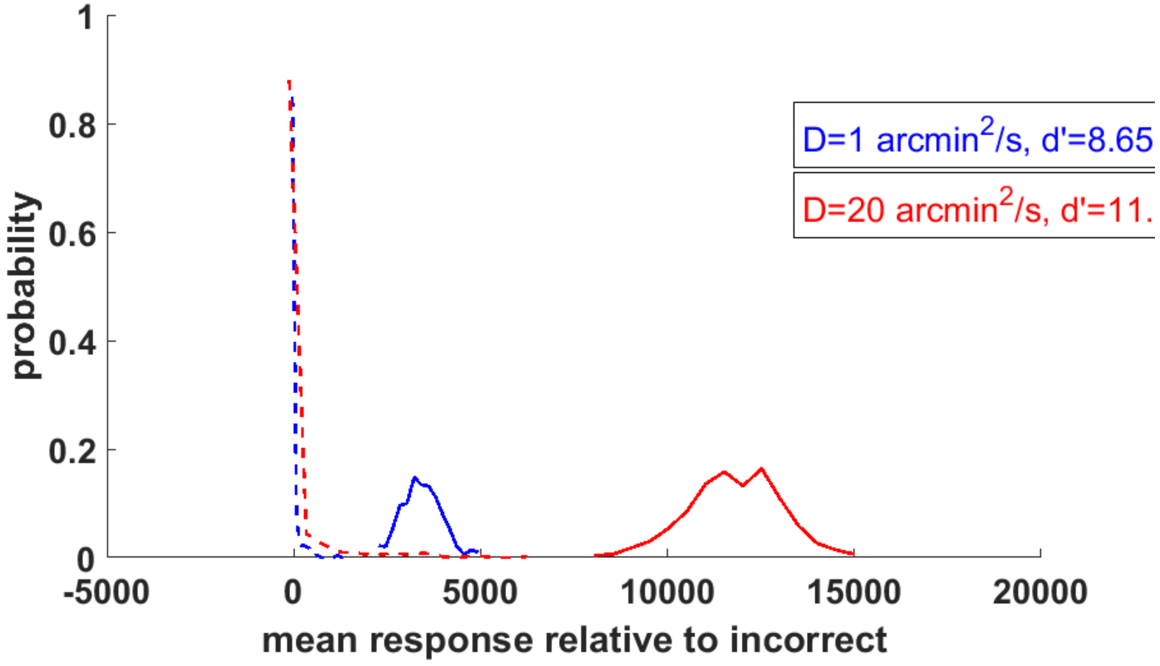
V1 Complex Cells: mean plateau response

*stimulus ramp

P-cells

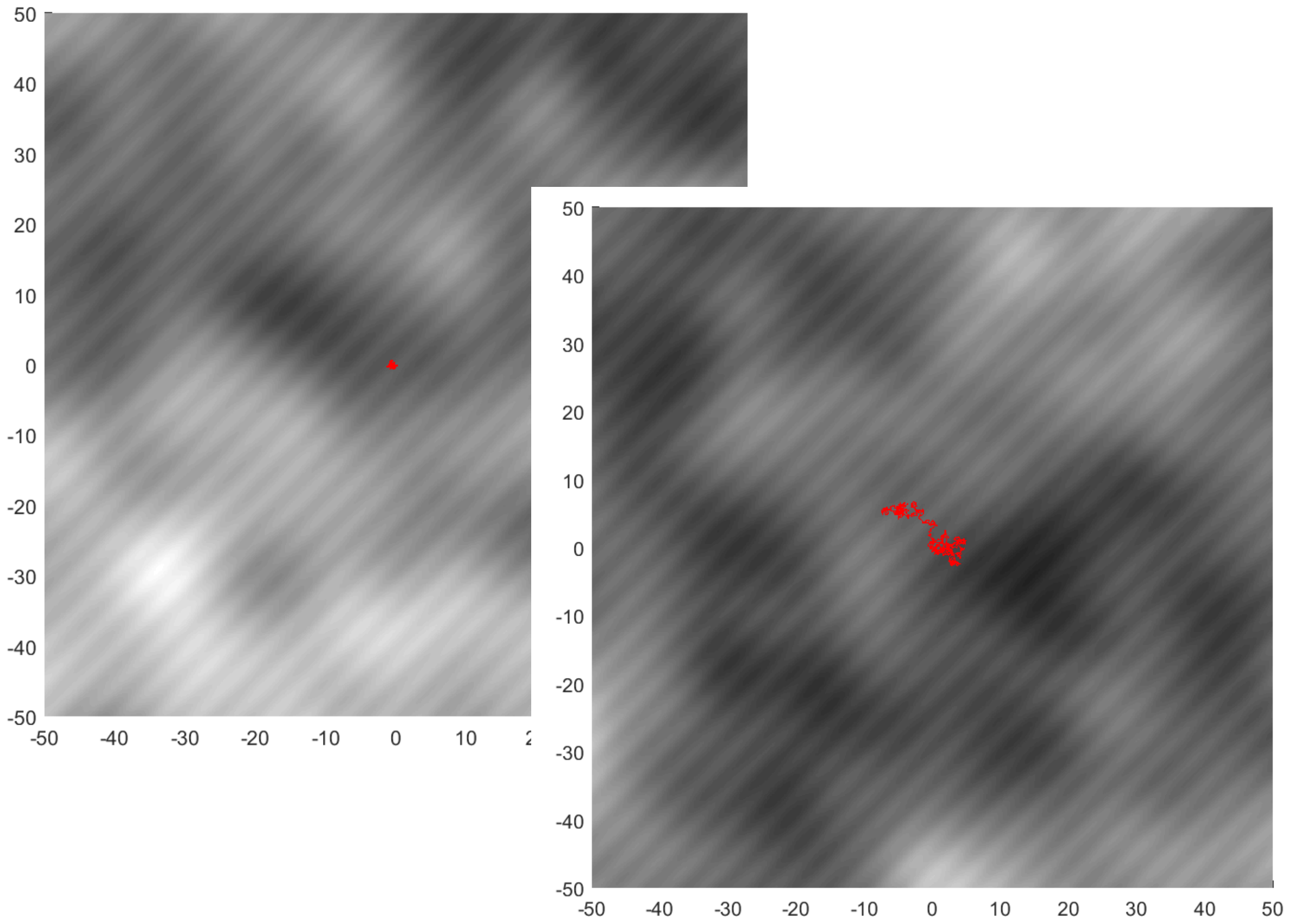


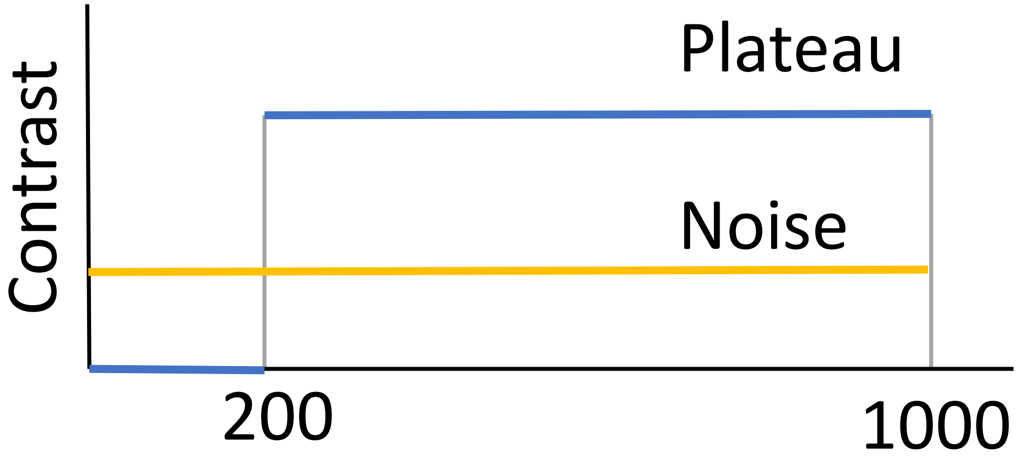
M-cells



Contribution of Temporal Structure

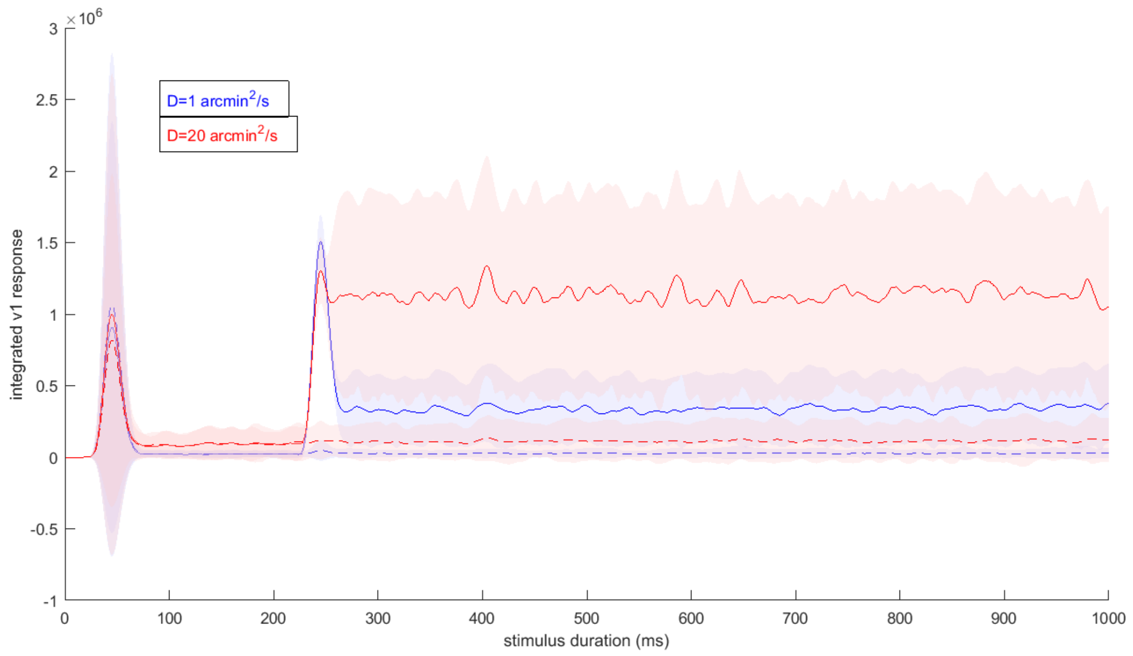
- Flash vs. modulations from drift

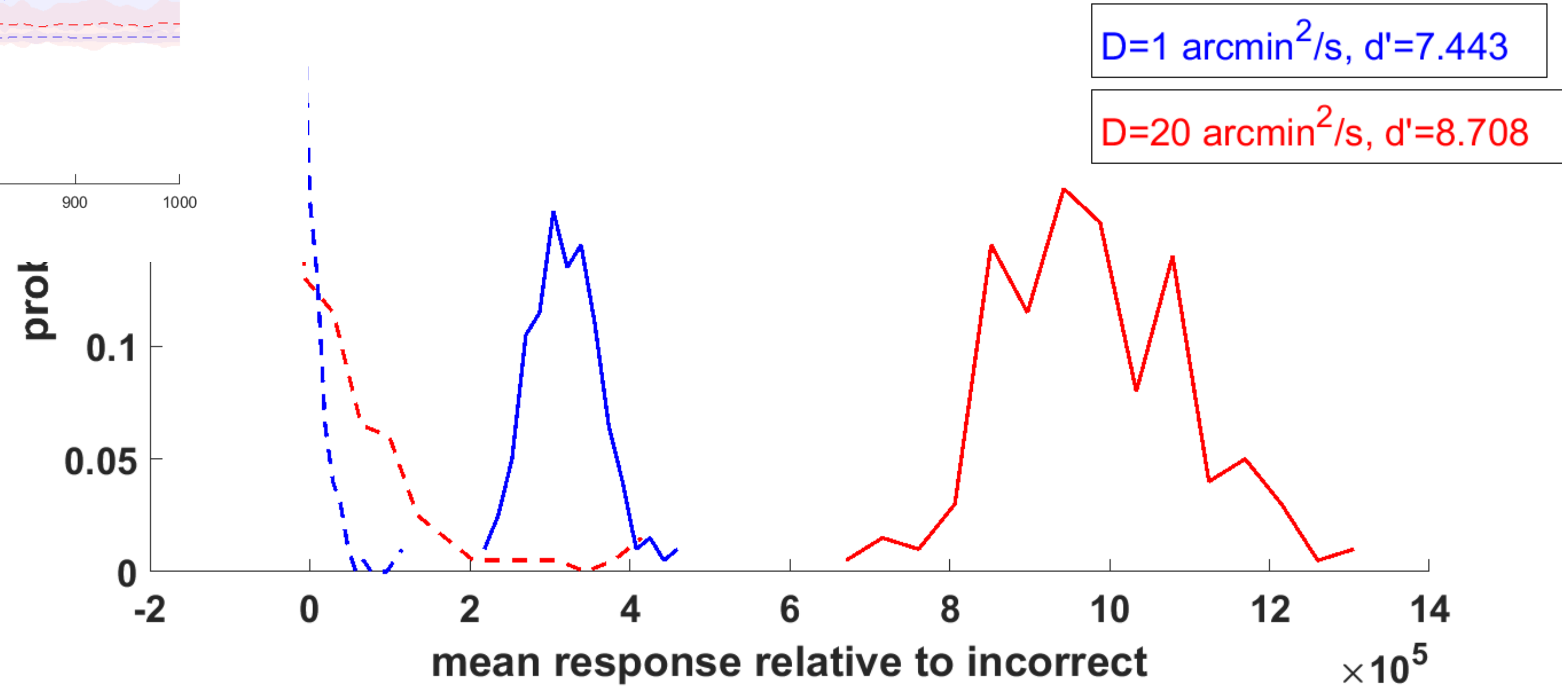




V1 Complex Cells: mean plateau response

*stimulus step





Next Steps

- V1 transient responses?
- Decrease range of eccentricities to test more specifically at 5-degree eccentricity: Can we resolve gratings greater than Nyquist because of drift?