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Extra Figures

2210 - A0390 Synaptic plasticity models predict that binocular treatments for amblyopia can outperform monocular treatments

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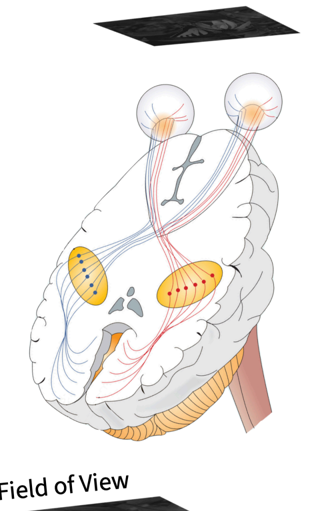
Purpose

Amblyopia is a common cause of visual impairment that results from unequal visual inputs during development, known to manifest through synaptic alterations in the visual cortex. What is not known is the detailed mechanisms of these synaptic changes and how these mechanisms impact the dynamics of recovery. Here we use a computational model of neural plasticity to compare multiple treatment strategies.

Methods

- Bienenstock, Cooper, and Munro (BCM) model of activity-dependent neural plasticity
- Compare the dynamics of amblyopia recovery at the neuronal level
- Treatment protocols:
  - optical correction
  - patching
  - atropine penalization
  - binocular therapies.
- Multiple sources for amblyopiagenesis
  - refractive error
  - strabismus

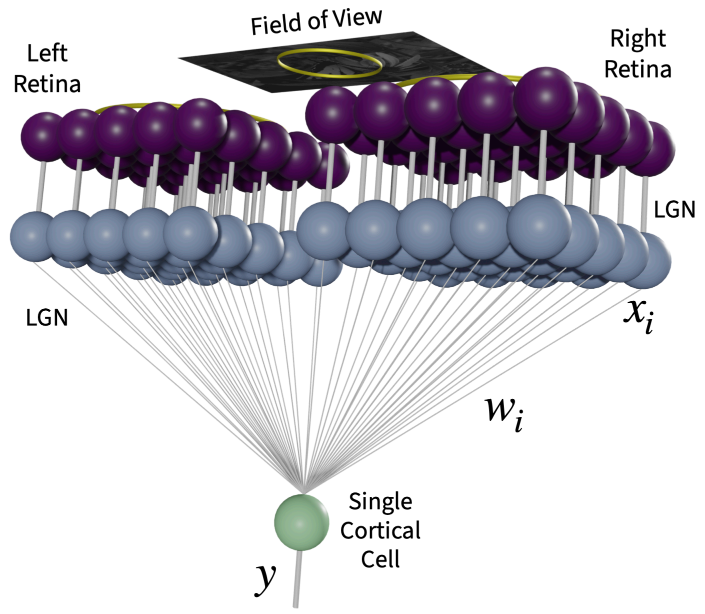


BCM equations for Synaptic Plasticity

$$y = \sigma\left(\sum_i x_i w_i\right)$$

$$\frac{dw_i}{dt} = \eta y (y - \theta_M) x_i$$

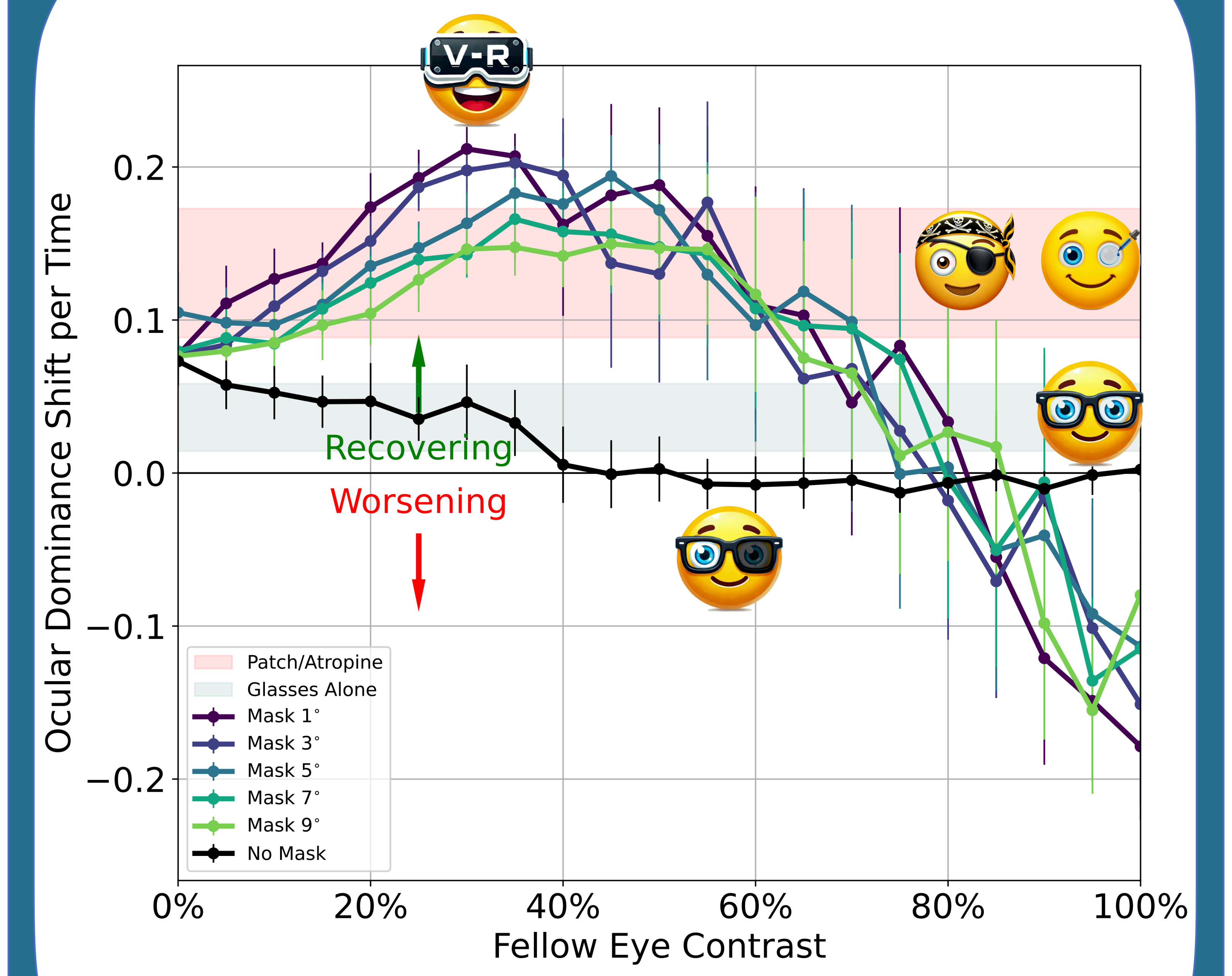
$$\frac{d\theta_M}{dt} = (y^2 - \theta_M)/\tau$$



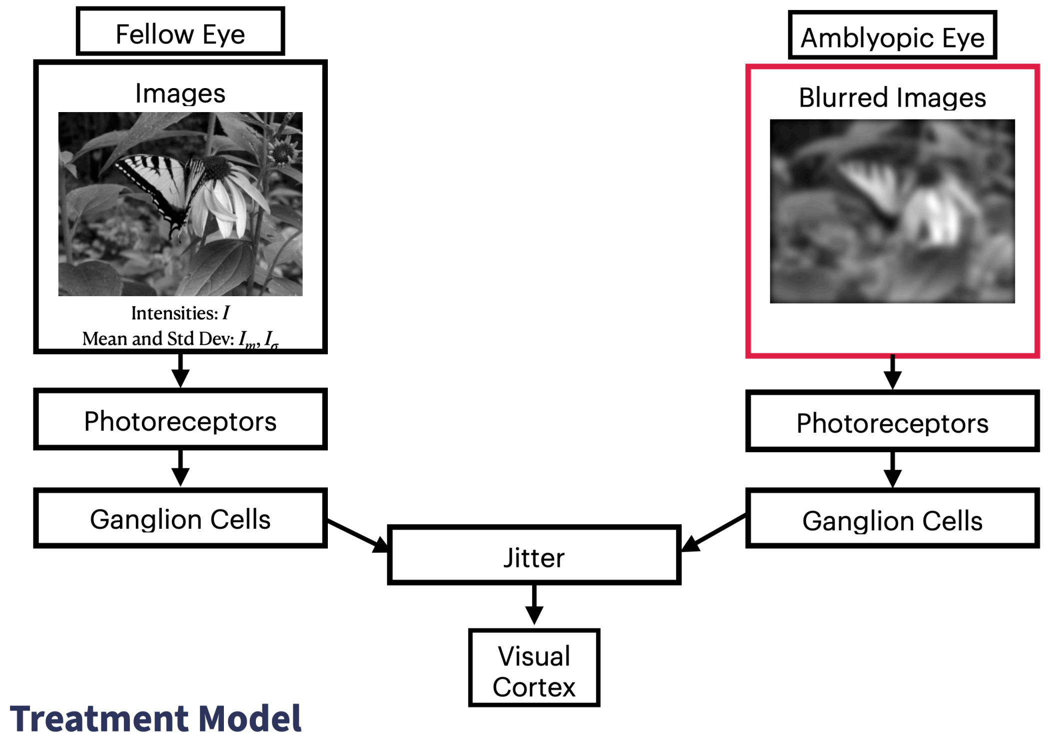
Results

- Recapitulated anisometropic amblyopia
- Ocular dominance remained stable even when simulating large angle strabismus
- Recovery achieved with dichoptic masks combined with an interocular contrast disparity exceeded that of patch and atropine treatments
- Patch and atropine treatment models produced faster recovery compared to a contrast disparity alone
- The rate of recovery depended on experimentally accessible treatment features
  - size of the dichoptic masks
  - magnitude of the contrast disparity
- The model suggests optimal values for these modifications
- Eye jitter and offset made very little if any difference on treatment response
- BCM theory of synaptic plasticity is sufficient to model anisometropic but not all of strabismic amblyopia
- Modeling can thus serve as a useful tool to compare therapeutic approaches and make specific clinical predictions

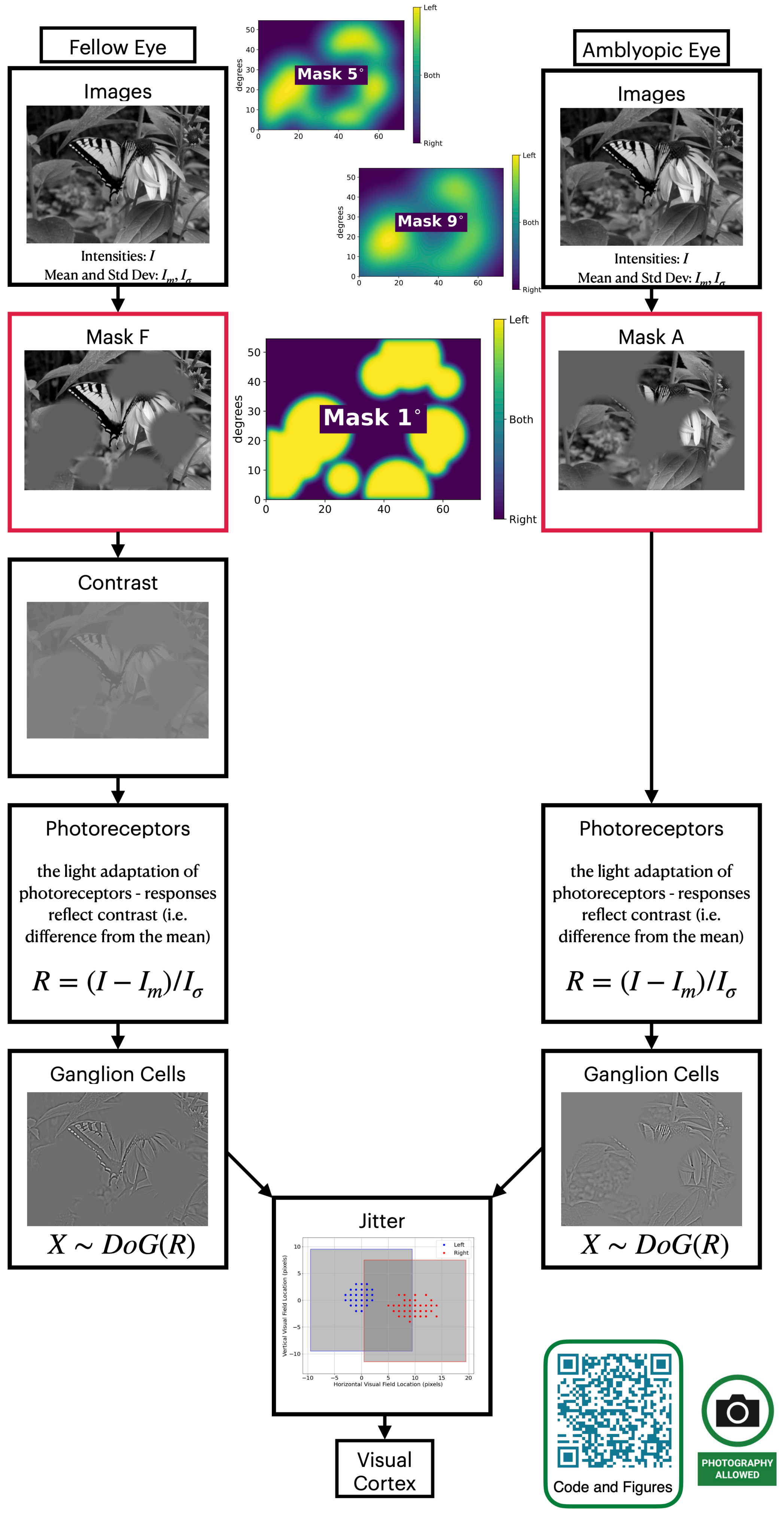
Synaptic plasticity models predict that (with small masks and moderate contrast disparity) **binocular treatments** for amblyopia can <u>outperform</u> **monocular treatments**



Deficit Model



Treatment Model



Code and Figures

PHOTOGRAPHY ALLOWED

Normal Vision Model

Normalization as a canonical neural computation

Matteo Carandini[1] and David J. Heeger[2]

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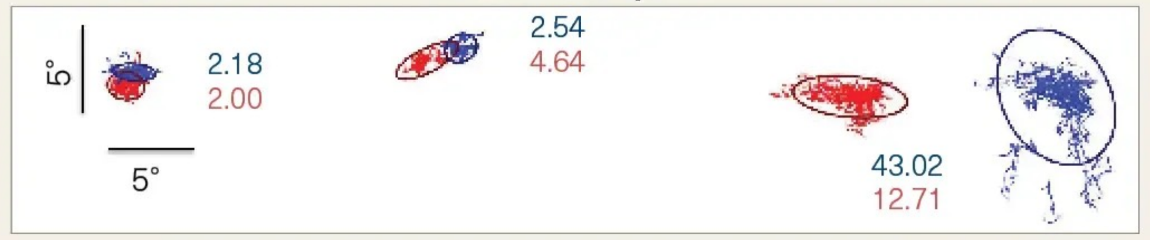
FIXATION INSTABILITY IN AMBLYOPIA

- Fixation instability has been reported in amblyopic patients*
- Amblyopia is a neurodevelopmental disorder secondary to abnormal visual experience during early childhood and can arise due to anisometropia, strabismus, deprivation or mixed mechanisms



*Gonzalez EG, Wong AM 2012; Submanian V, Jost R, Birch E 2013; **Ghasia FF** Plos One 2016. Kang S, **Ghasia FF**: JEMR 2019, Scaramuzzi M, **Ghasia FF**, PIBR 2018, Scaramuzzi M, **Ghasia FF** Plos One 2020, Scaramuzzi M, **Ghasia FF** Scientific Rep 2021*

J Comp Neurol. 2010 June 1; 518(11): 2051–2070. doi:10.1002/cne.22321.

Receptive-field Properties of V1 and V2 Neurons in Mice and Macaque monkeys

Gert Van den Bergh[1,2], Bin Zhang[1], Lutgarde Arckens[2], and Yuzo M. Chino[1]

Images

Intensities: I

Mean and Std Dev: I_m, I_σ

Photoreceptors

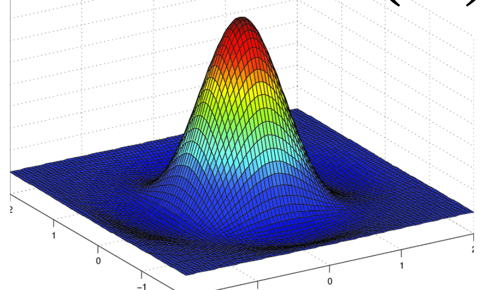
the light adaptation of photoreceptors - responses reflect contrast (i.e. difference from the mean)

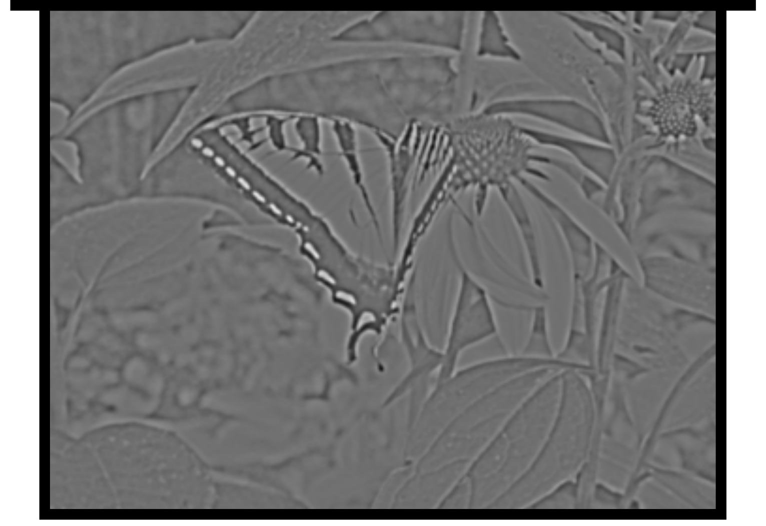
$$R = (I - I_m)/I_\sigma$$

Ganglion Cells

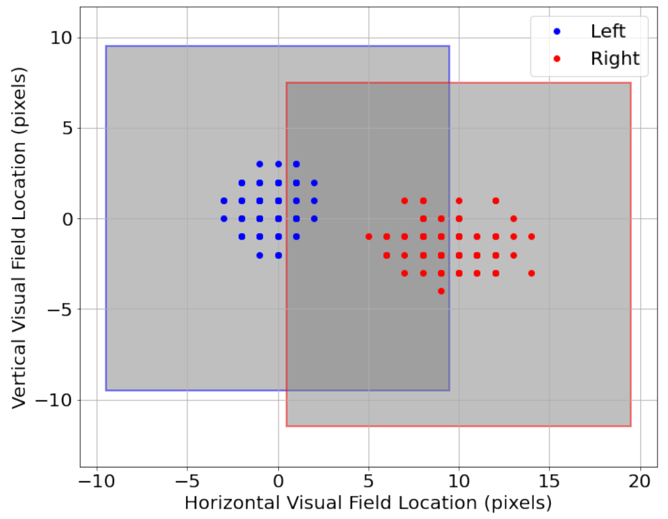
contrast normalization effect of a suppressive field, e.g. difference of Gaussians

$$X \sim DoG(R)$$





Jitter



Visual Cortex

Ghasia FF Plos One 2016.

Normal: variation ~ 2° + 2°

Amblyopic: variation ~ 2° + 4°

Bergh et al 2010

V1 RF size: ~ 8°

bblais

V1 RF size: 19px —> 0.4°

Jitter: $\mu = 9, \sigma = 9$

$\mu = 0, \sigma = 9$
Ocular Dominance Shift per Time
Fellow Eye Contrast
Recovering
Worsening
Patch/Atropine
Glasses Alone
Mask 1°
Mask 3°
Mask 5°
Mask 7°
Mask 9°
No Mask
0%
20%
40%
60%
80%
100%
0.2
0.1
0.0
−0.1
−0.2
$\mu_r = 0, \mu_c = 9, \sigma_r = 0, \sigma_c = 9$
$\mu = 18, \sigma = 9$
0.20
0.15
0.10
0.05
0.00
−0.05
−0.10
−0.15
−0.20
$\mu_r = 0, \mu_c = 9, \sigma_r = 0, \sigma_c = 0$
$\mu = 9, \sigma = 9$
$\mu_r = 0, \mu_c = 9, \sigma_r = 0, \sigma_c = 18$