Expanded population receptive field size in early visual cortex following the loss of one eye

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BACKGROUND

Compared to binocularly intact individuals, the removal of one eye results in changes in:

1. Visual Behaviour:
- Increased foveal acuity[1]
- Increased contrast sensitivity[2]
- Superior perception at low-contrast levels[1,3,4]

2. Brain Structure:
- Reduced optic tract volume
  - Less severe contralateral to remaining eye[5]
- Decreased LGN volume
  - Less severe contralateral to the remaining eye[5]
- Decreased tract coherence of optic radiations contralateral to remaining eye[6]
  - Suggests increased axonal crossing
- Increased surface area and gyrification in V1[7]
- Increased surface area in ocular dominance columns associated with remaining eye[8]
  - Especially in contralateral hemisphere

3. Brain Function:
- Visual stimulus activates double the volume in contralateral primary visual cortex (V1)[9]
- Loss of mutual inhibition between ocular dominance columns
- Increased functional activity in multisensory processing regions[10]

Research Questions

pRFs, measured using functional MRI, describe the combined activation of many thousands of neurons, and can be used to characterize the receptive field properties of visual cortex

Given that there are behavioural, structural and functional differences between individuals with one eye and binocular-viewing controls, we asked:

1. Are there any retinotopic differences between groups?

2. Are those differences isolated to the contralateral hemisphere?

METHODS

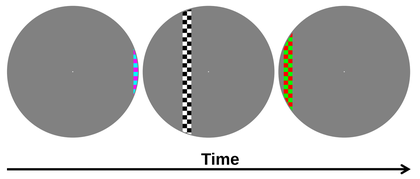
Binocular Viewing Controls (BV)

- N = 7
- Age (M = 34 years, SD = 9 years)
- 6 right eye dominant

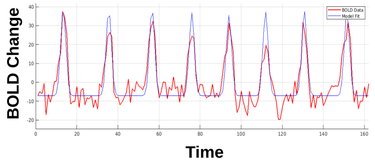
Monocular Enucleation Group (ME)

- N = 5
- Eye enucleation (surgical removal of one eye)
- 2 early (< 2 years old)
- 4 with right eye remaining
- Age (M = 56 years, SD = 8 years)
- Age of enucleation (M = 59 months, SD = 46 months)

Population Receptive Field Stimulus Mapping[11]

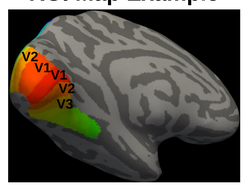


Fitted Model Example



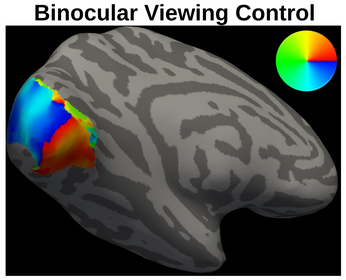
- For each voxel, a model was fit to identify the pRF size and location that best described the measured BOLD response
- We restricted our analysis to voxels in early visual cortex (V1-V3) for which the pRF model explained at least 15% of BOLD variance
- Linear regressions were used to describe the relationship between pRF size and eccentricity for each ROI

ROI Map Example

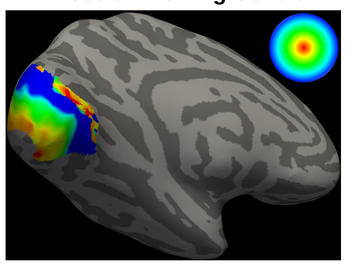


RESULTS

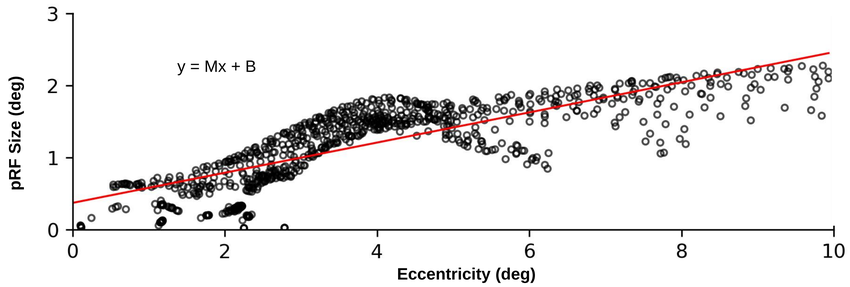
Polar Angle Map Example Binocular Viewing Control



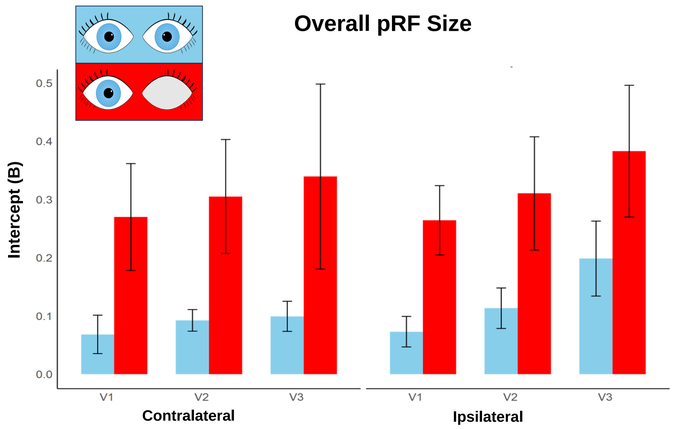
Eccentricity Map Example Binocular Viewing Control



Linear Regression in V1 Binocular Viewing Control Example

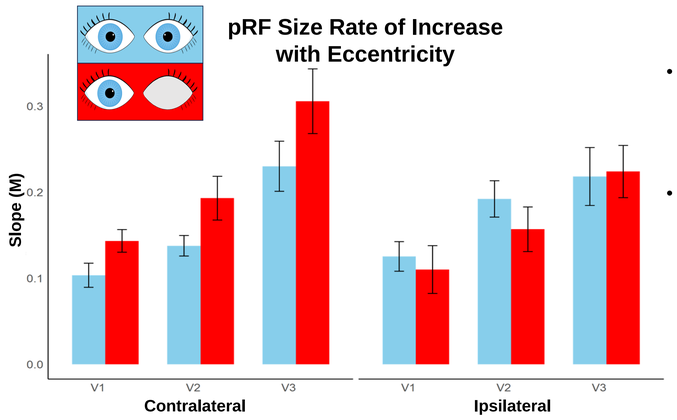


Overall pRF Size



- pRFs are larger overall in individuals with one eye
- Effect is seen in both hemispheres

pRF Size Rate of Increase with Eccentricity



- pRF size more steeply increases with eccentricity in individuals with one eye
- Effect is isolated to the contralateral hemisphere

CONCLUSIONS

- In individuals with one eye, pRFs are larger overall in bilateral early visual cortex
- In individuals with one eye, pRF size increases with eccentricity at a steeper rate in early visual cortex contralateral to the remaining eye
- Aligns with some of the observed structural and functional changes[6,8,9]

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