

Stereovision in primates

A neuroimaging and psychophysics investigation

Yseult Héjja-Brichard

ECO₃ meeting – Feb, 1st



Background

**Bsc
Psychology**
Grenoble & Leipzig

**Msc
Cognitive
Psychology**
Grenoble

**Msc + PhD
Cog & Behav
Neuroscience**
Toulouse

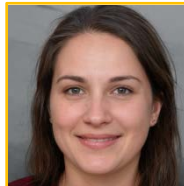
PostDoc
*Montpellier
& Baltimore*

**MAX
PLANCK
INSTITUTE** FOR
HUMAN
COGNITIVE AND BRAIN SCIENCES
LEIPZIG

**LP
NC**


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UMR5549


CENTRE D'ÉCOLOGIE
FONCTIONNELLE
& ÉVOLUTIVE



Stereovision: Outline



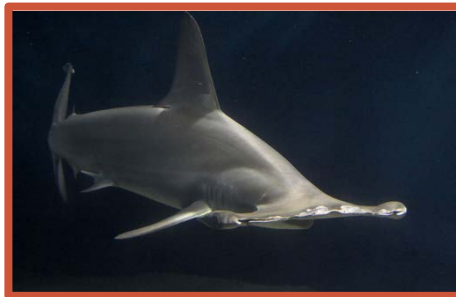
Which species? Which functions? Requirements?

How does the (primate) brain compute a depth percept?
Binocular disparities

The case of motion in depth

Depth perception and natural statistics

Many species, of different taxa



... have stereovision

Stereopsis is useful for

- Estimating distances
- Breaking camouflage
- Perceiving motion in depth

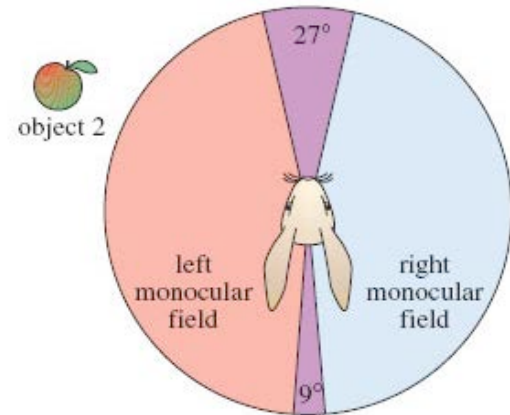


→ Catching a (moving) target, manipulating tools

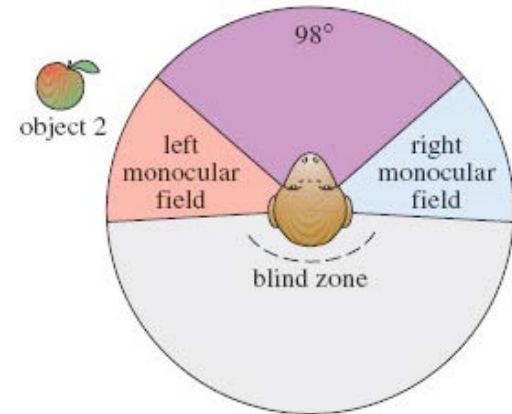


Key ingredients for stereopsis

- **Binocular overlap**
- Good visual acuity in both eyes
- Accurate coordination between the eyes in all gaze directions
- Ability of the brain to fuse two slightly different retinal images



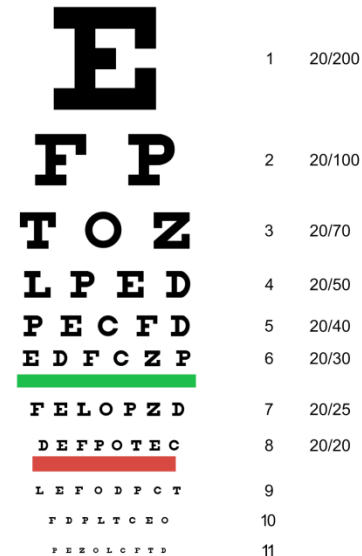
(a) rabbit



(b) monkey

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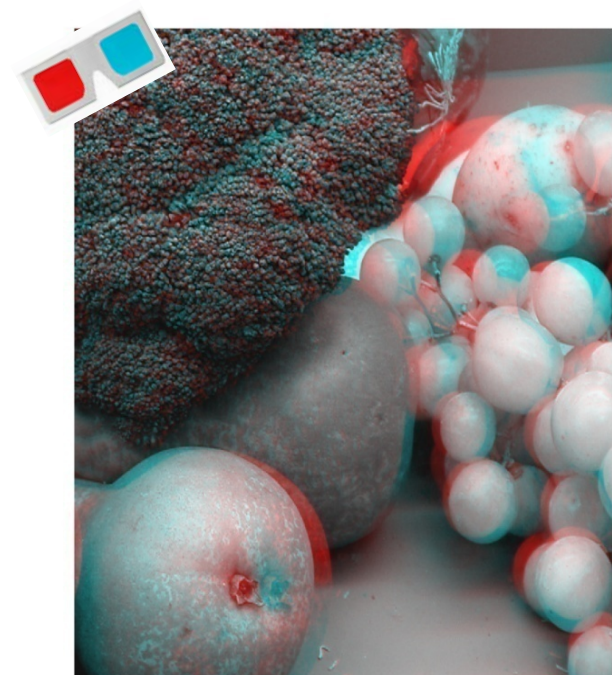


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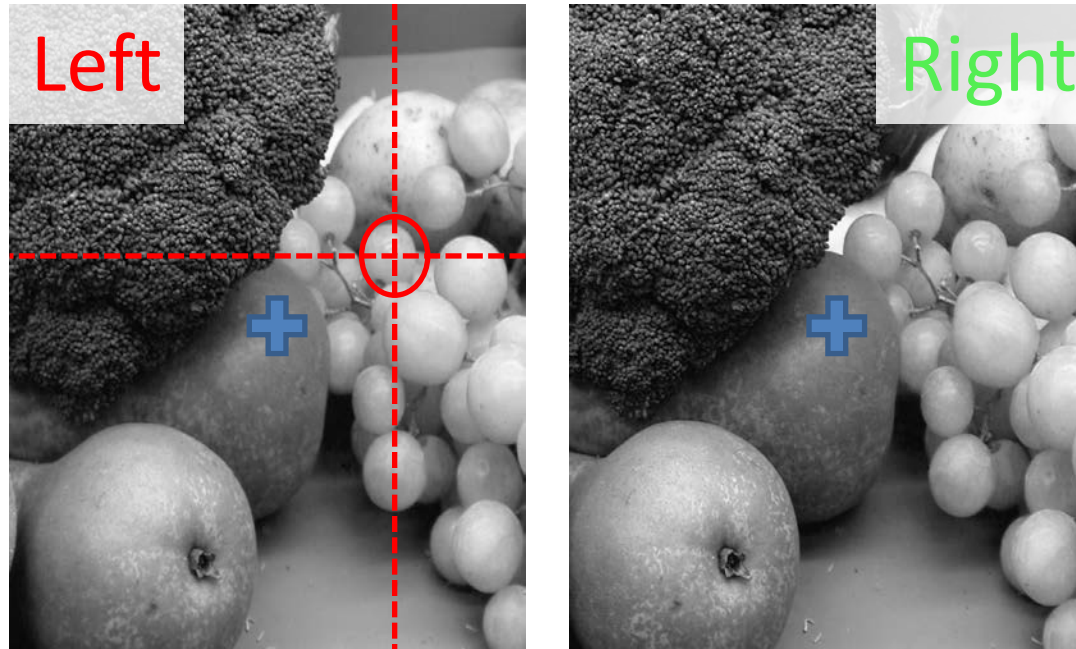
Horizontal binocular disparities



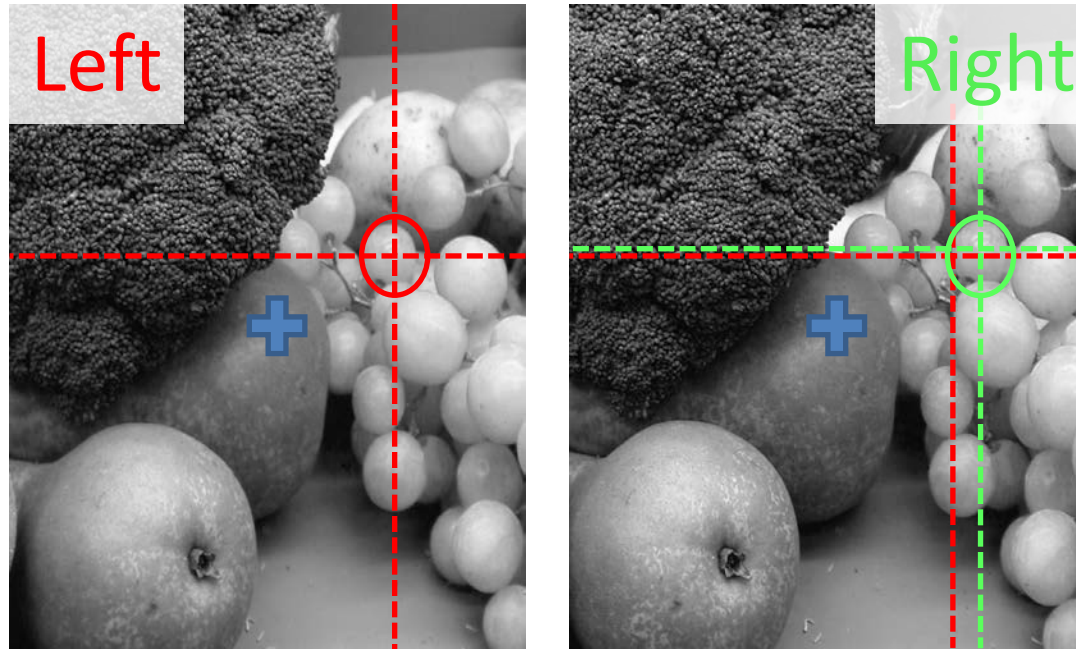
Horizontal binocular disparities



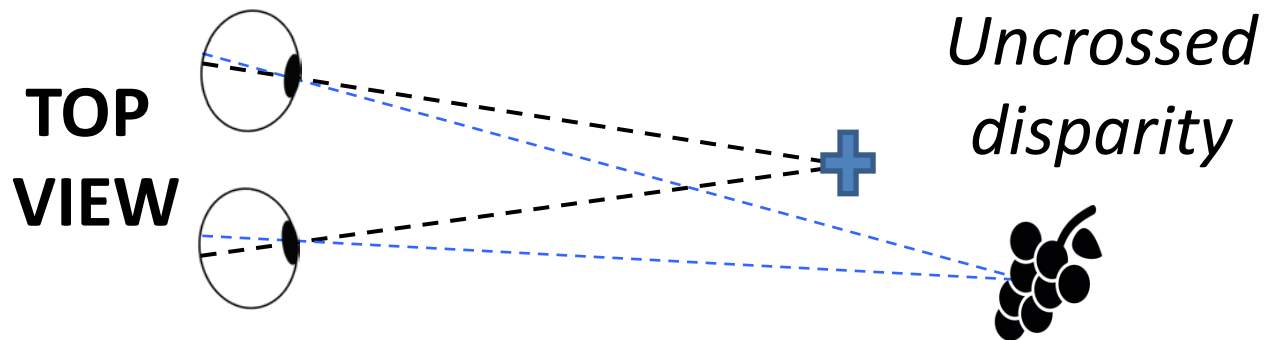
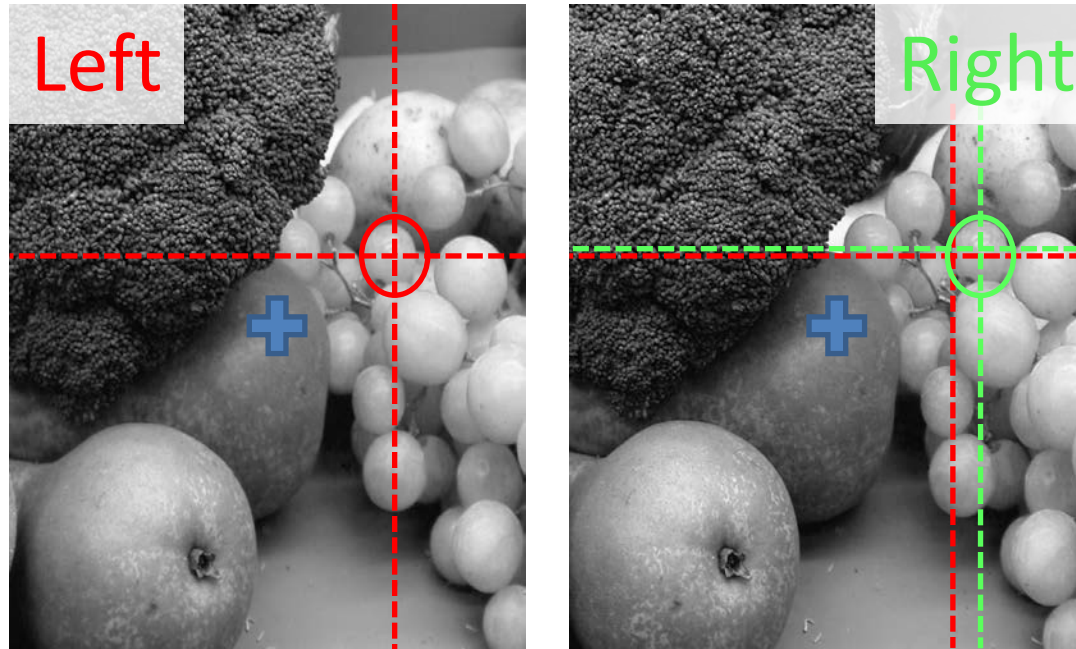
Horizontal binocular disparities



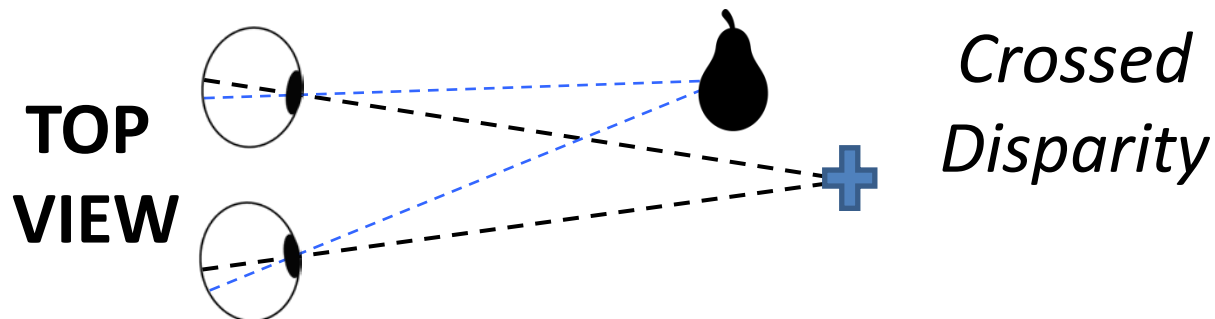
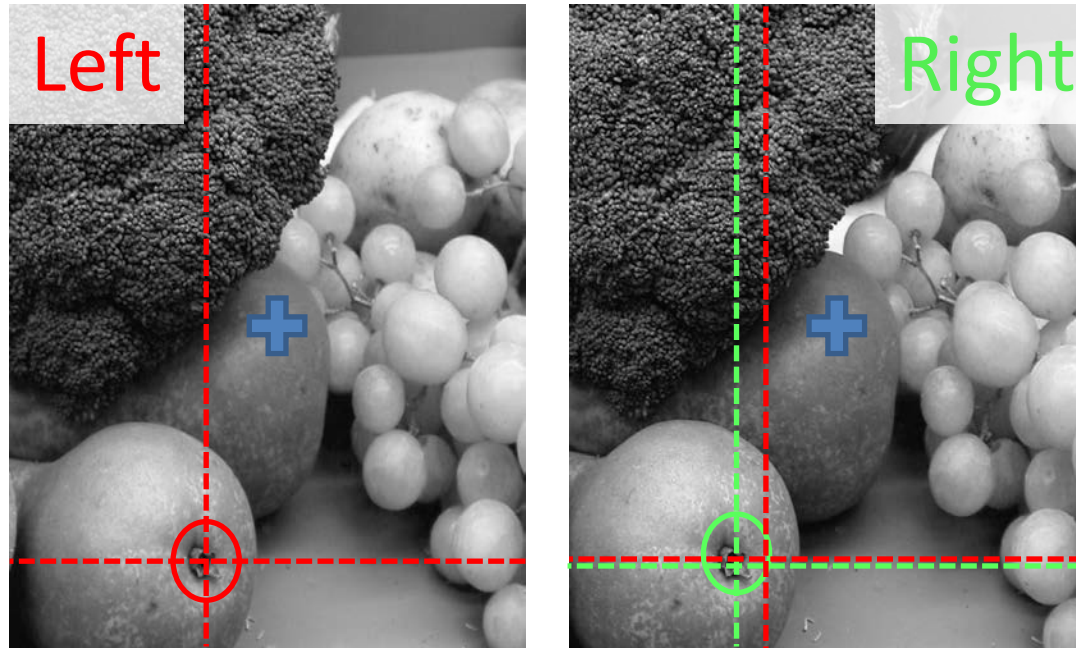
Horizontal binocular disparities



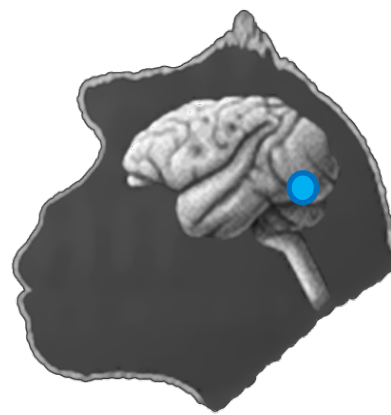
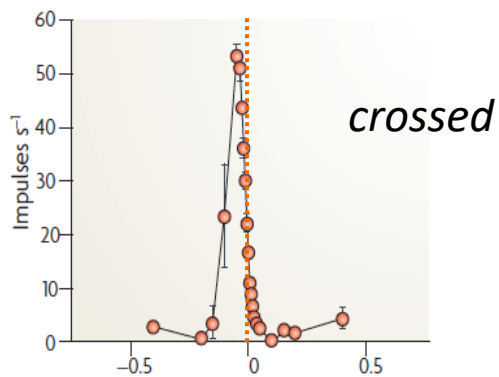
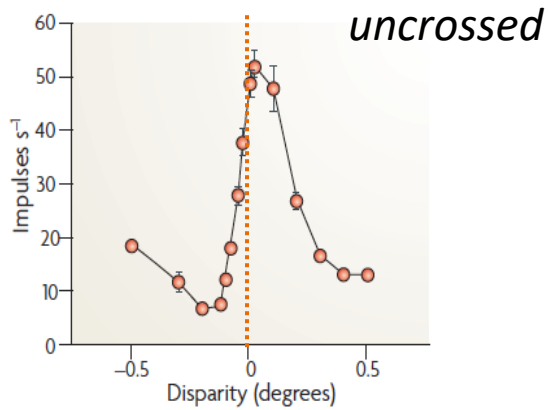
Horizontal binocular disparities



Horizontal binocular disparities



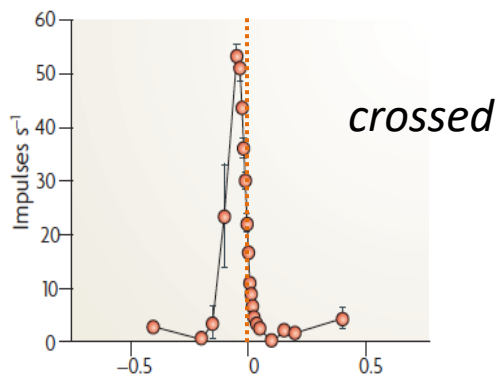
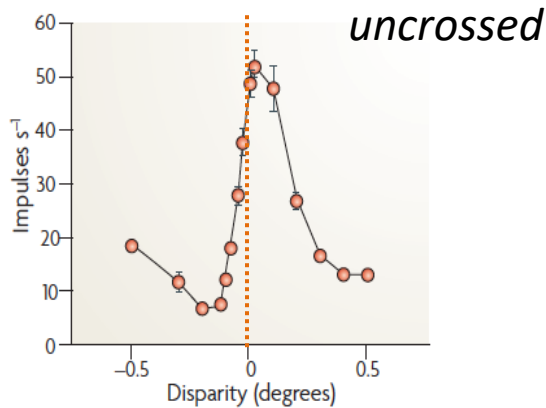
Integration of binocular disparities



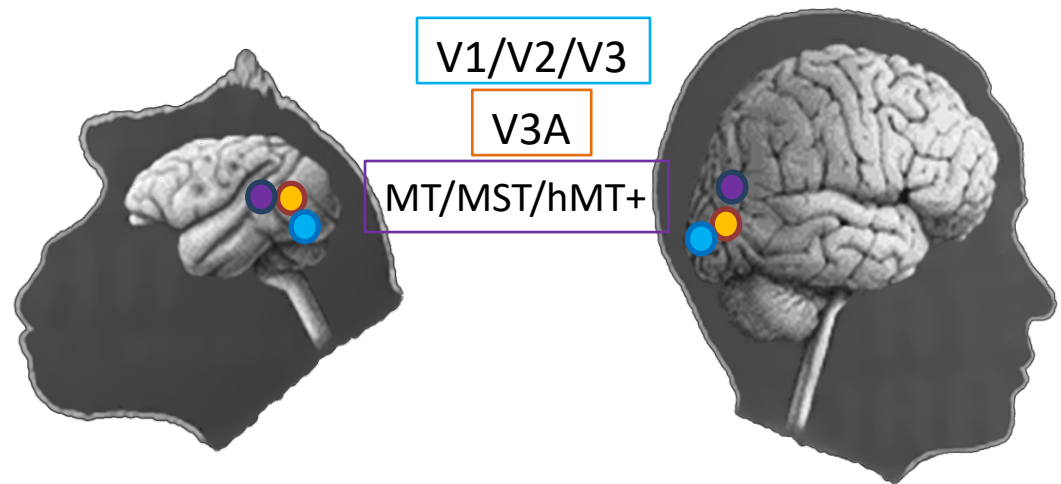
V1/V2/V3

Parker, 2007

Integration of binocular disparities



Parker, 2007

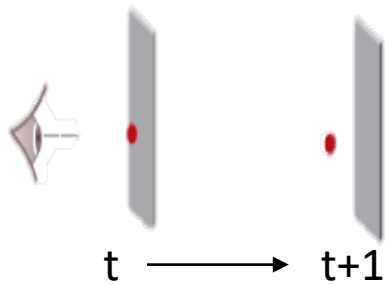


in most visual areas

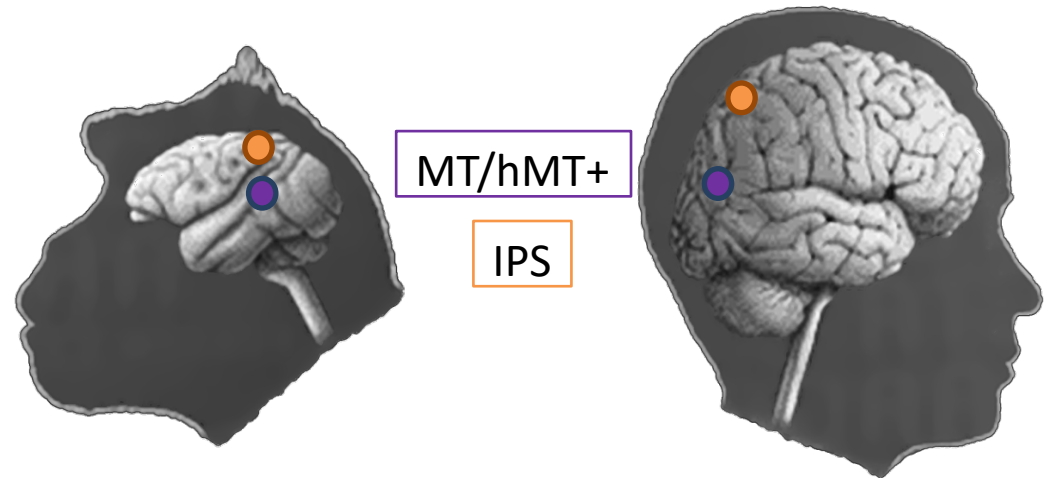
E.g.: Hubel & Wiesel, 1970; DeAngelis et al., 1998; Janssen et al., 1999; Uka et al., 2000; Taira et al., 2000; Hinkle & Connor, 2001; Tsao et al., 2003; Durand et al., 2009; Likova and Tyler, 2007; Rokers et al., 2009; Sanaka & DeAngelis, 2014; Czuba et al., 2014; Kaestner et al., 2019

Integration of disparity gradients

Temporal gradients



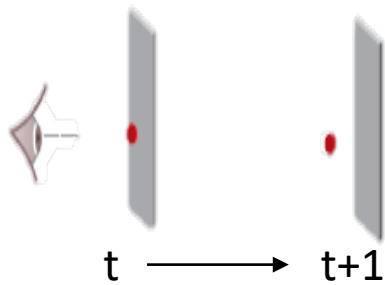
Changing disparity over time



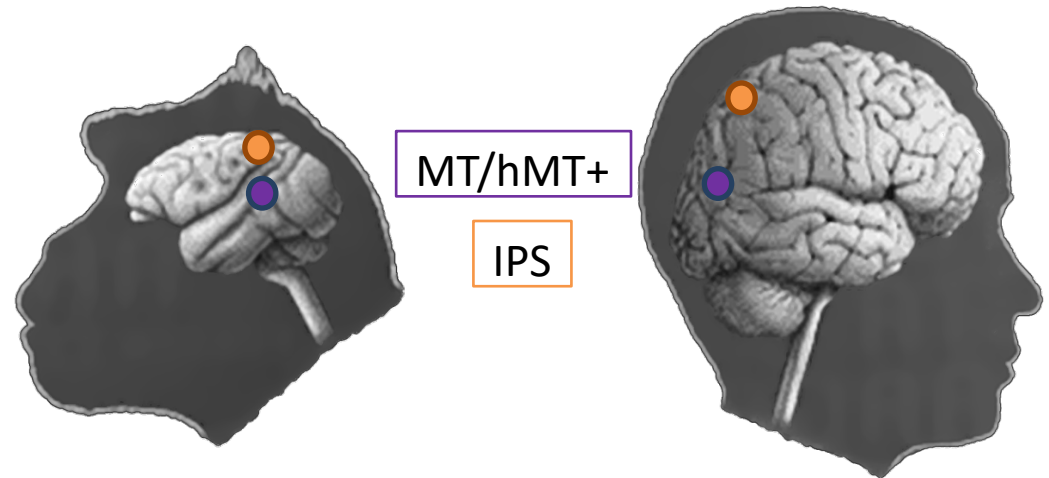
Likova and Tyler, 2007; Rokers et al., 2009; Sanaka & DeAngelis, 2014; Czuba et al., 2014; Kaestner et al., 2019

Integration of disparity gradients

Temporal gradients



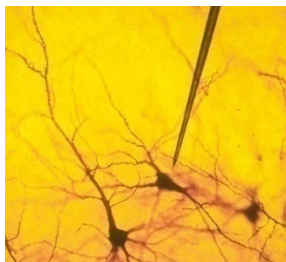
Changing disparity over time



→ Barely studied: Main focus on 2D motion and on MT/hMT+ but some differences might exist

→ Limited understanding of 3D motion despite its ecological relevance

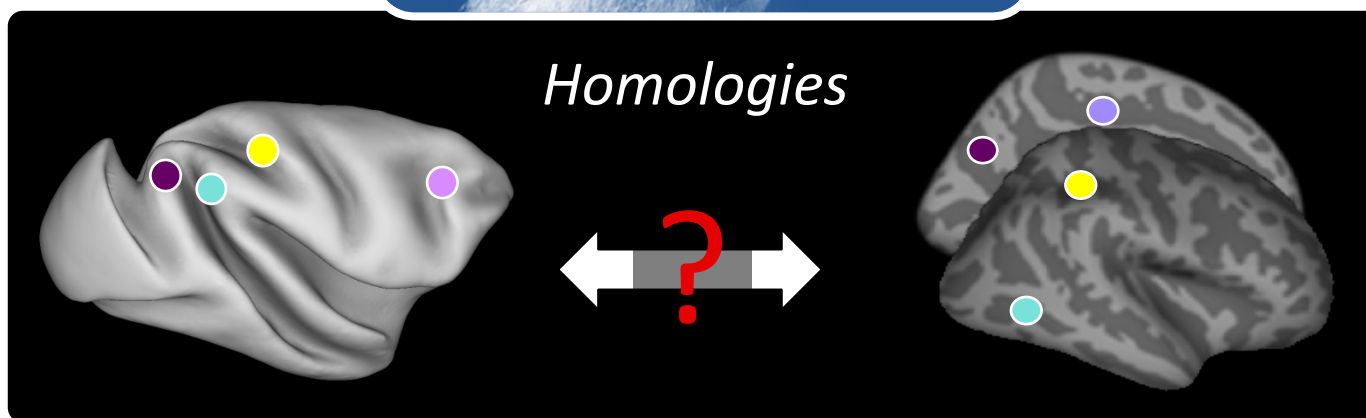
Monkey fMRI



electrophysiology

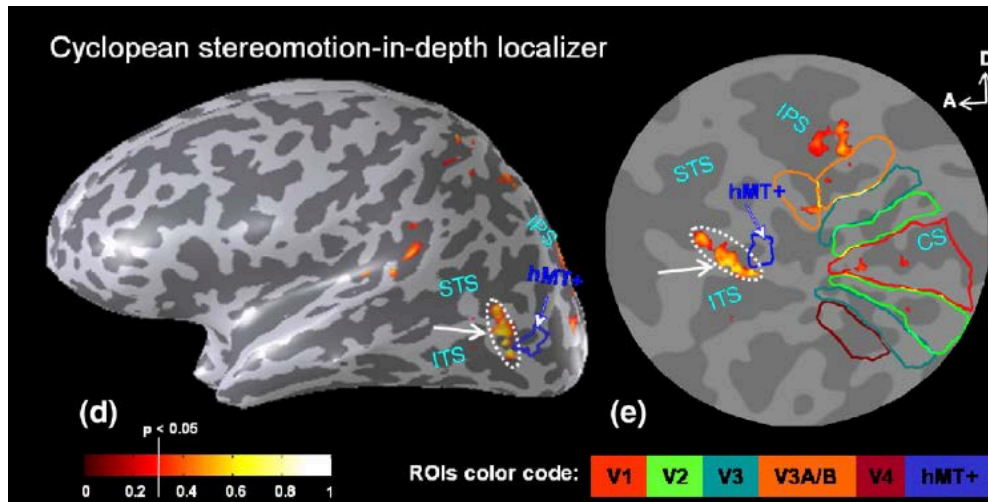


fMRI



Stereomotion: CDOT processing

→ Cyclopean StereoMotion area



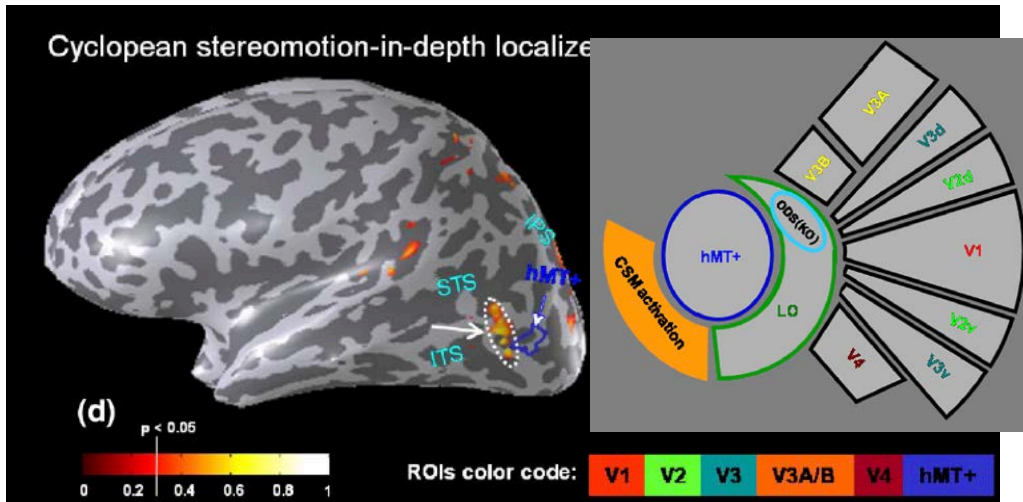
Likova & Tyler, 2007

Héjja-Brichard, Y., Rima, S., Rapha, E., Durand, J.-B., Cottureau, B.R. (2020). Stereomotion processing in the non-human primate brain. Cerebral Cortex.

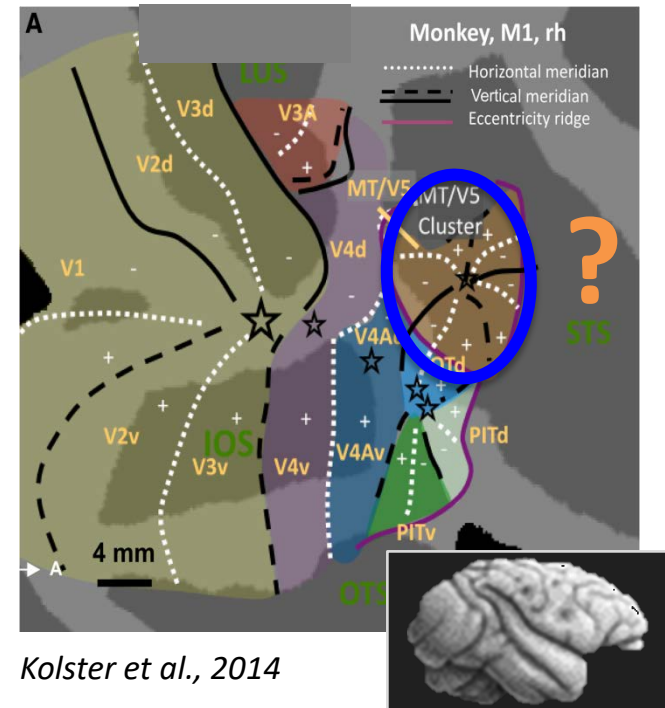
Stereomotion: CDOT processing



→ CSM area in macaque?



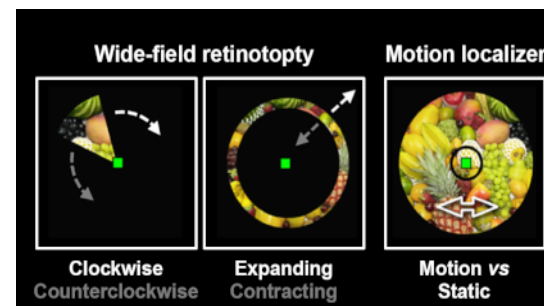
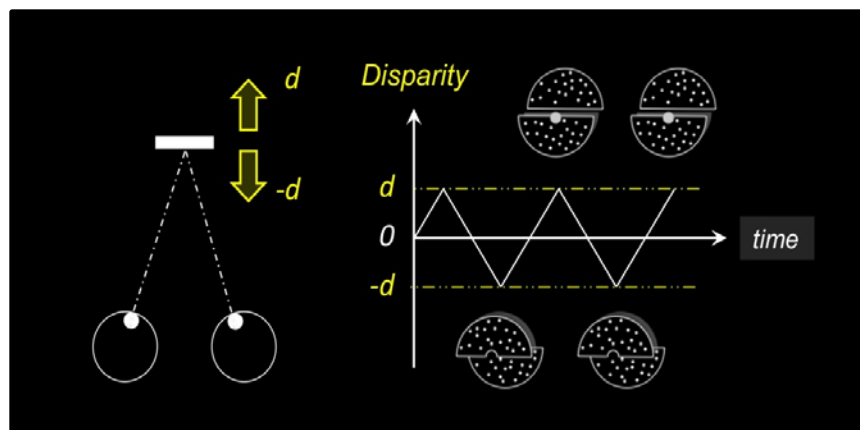
Likova & Tyler, 2007



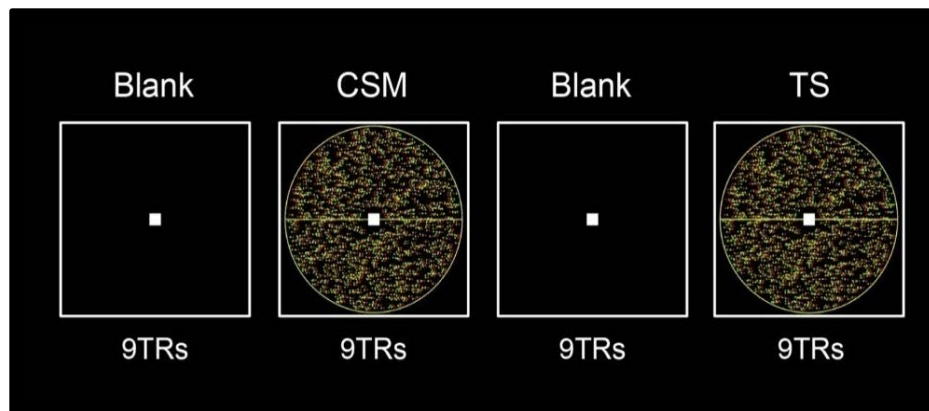
Kolster et al., 2014

Héjja-Brichard, Y., Rima, S., Rapha, E., Durand, J.-B., Cottureau, B.R. (2020). Stereomotion processing in the non-human primate brain. Cerebral Cortex.

Experimental paradigm

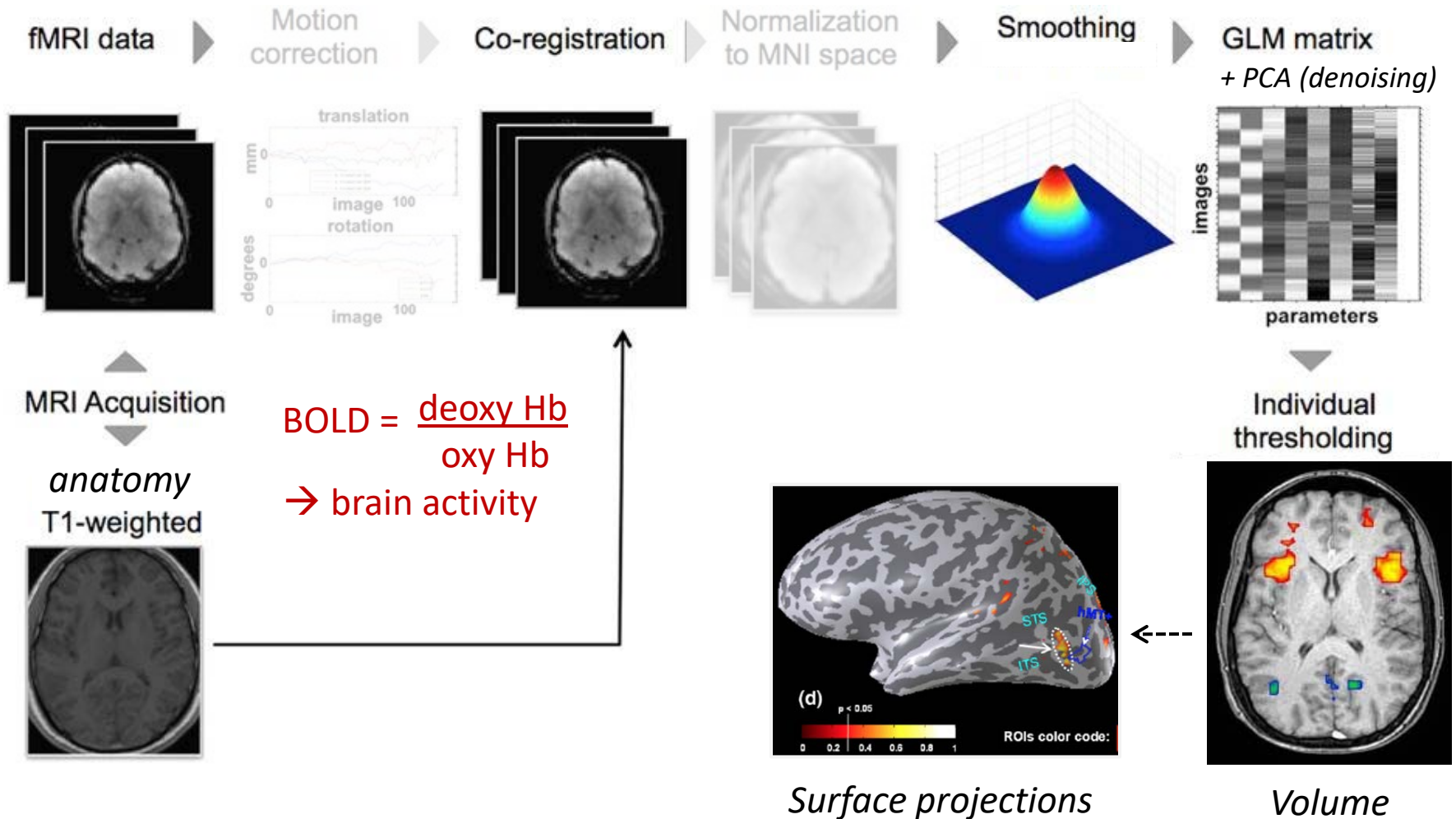


Rima et al. (2020)

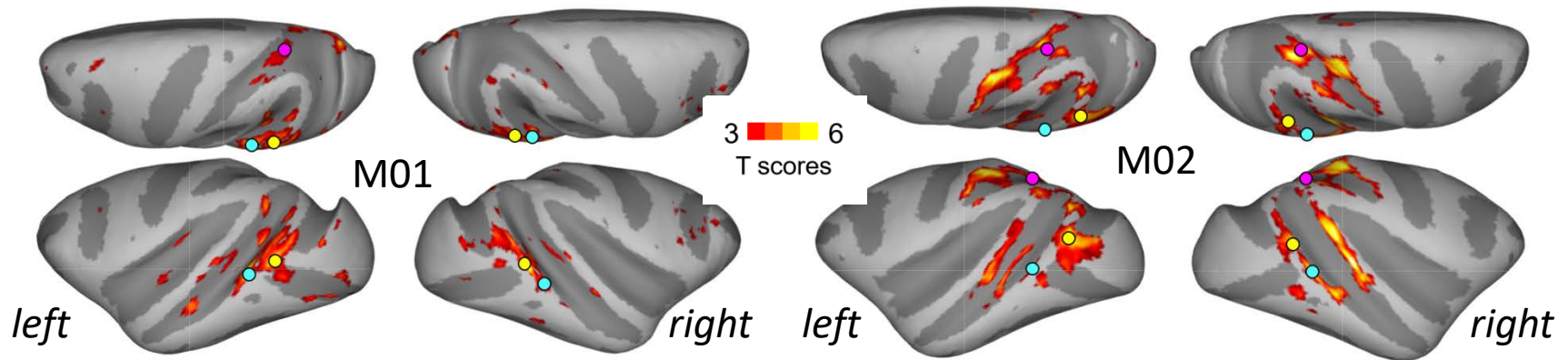


2 macaques
43 and 47 runs
BOLD signal

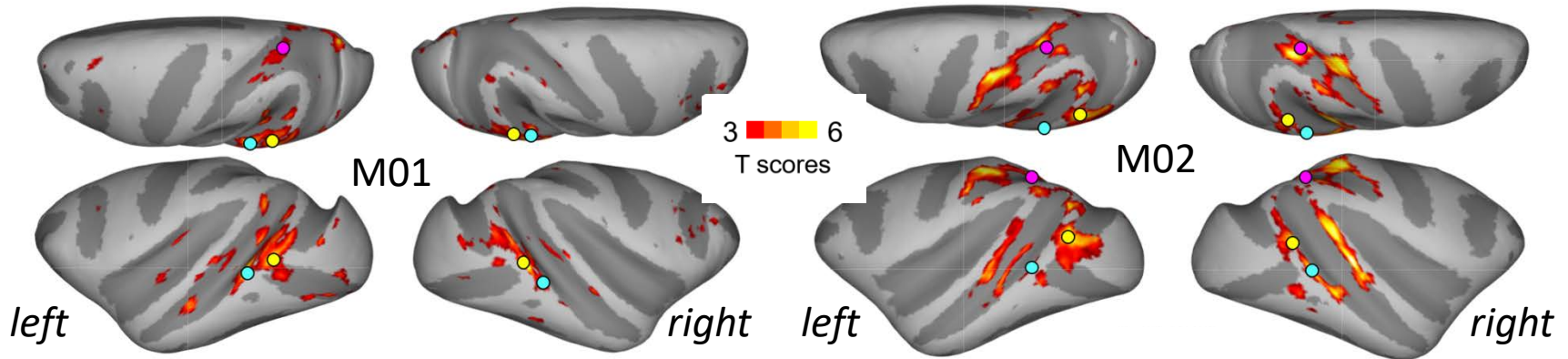
BOLD fMRI: A quick overview



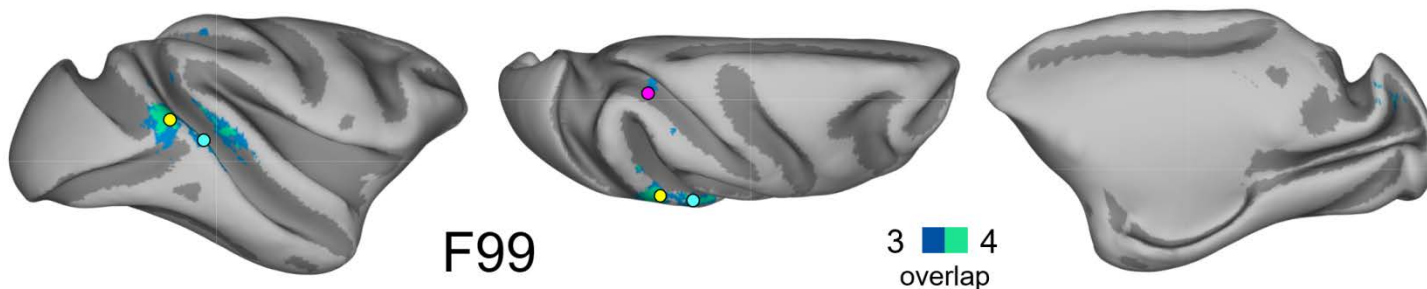
Projections on the individual surfaces



Projections on the individual surfaces

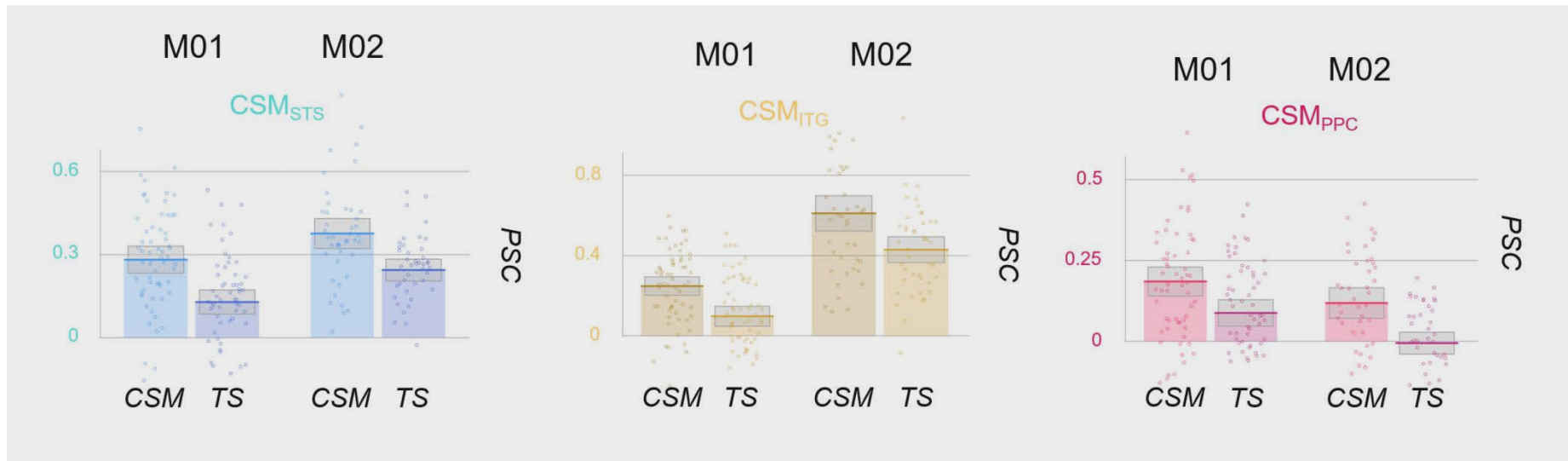
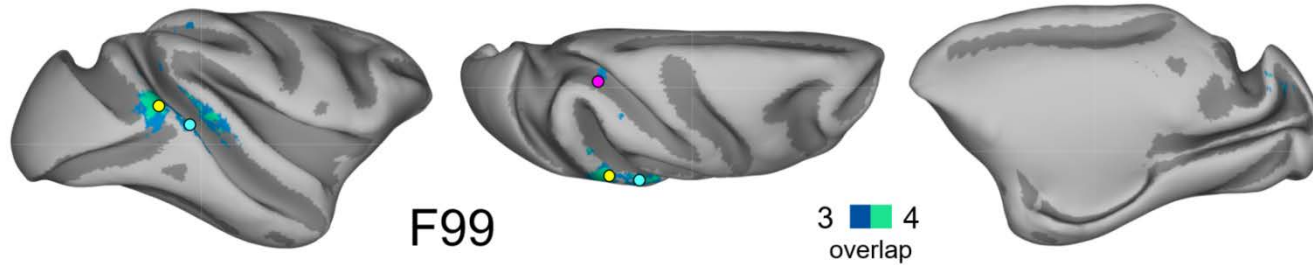


Projection on the F99 template: Overlap



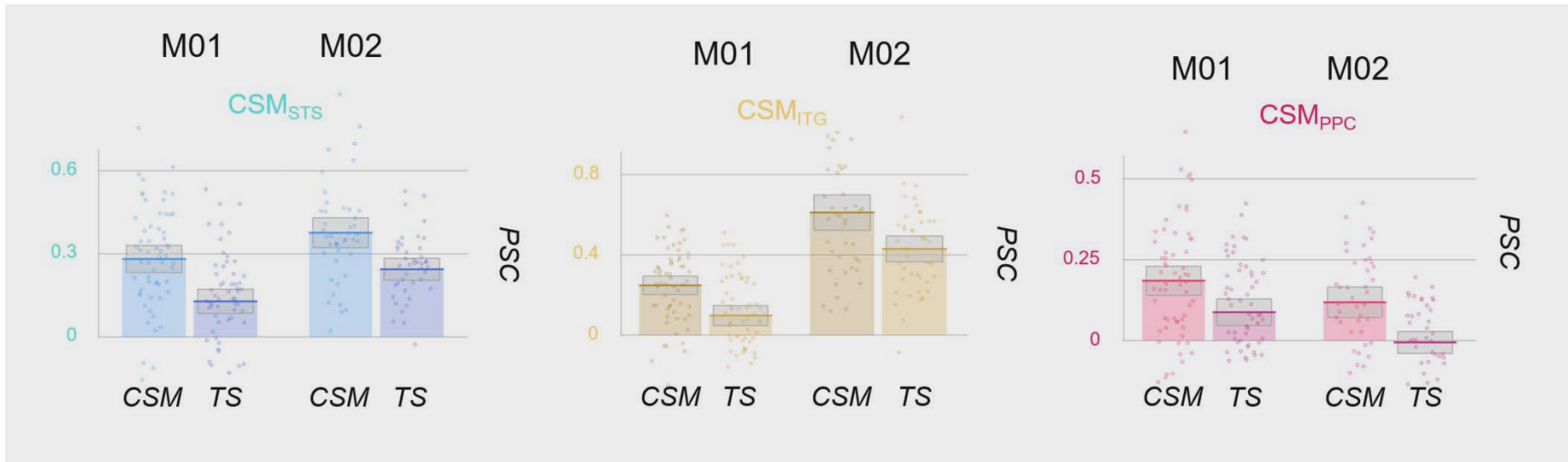
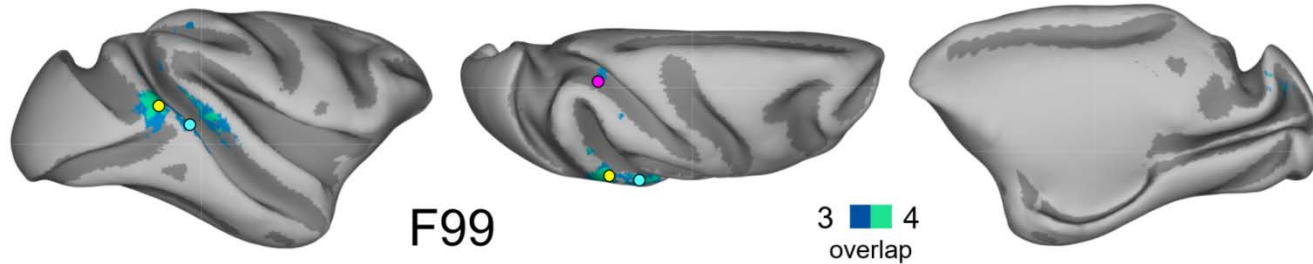
ROI analysis

$$\text{PSC} = \frac{\text{condition}}{\text{baseline}}$$



ROI analysis

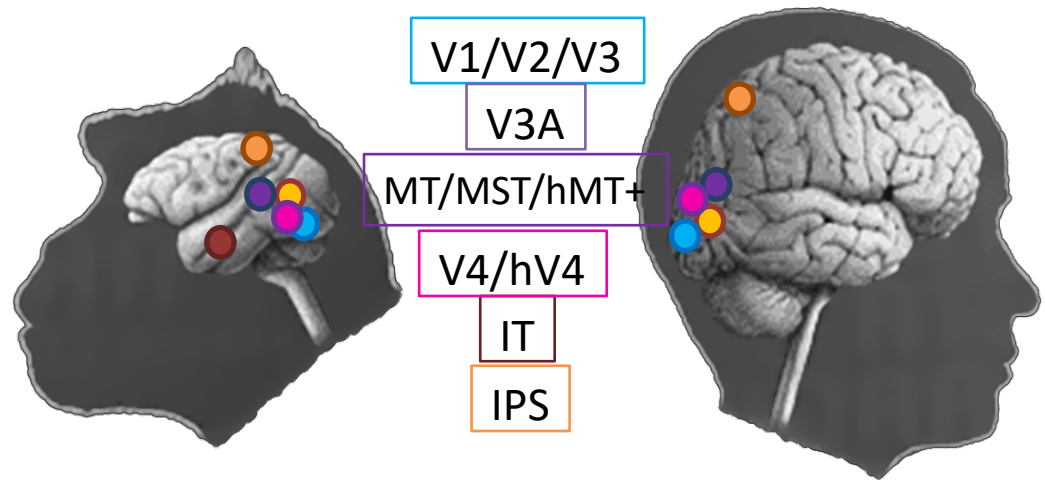
$$\text{PSC} = \frac{\text{condition}}{\text{baseline}}$$



Three areas with significant activations for CSM + tendency in the MT cluster (FST, MSTv)
One area found to respond exclusively to stereomotion
Similar networks for humans and macaques

Integration of disparity gradients

Spatial gradients

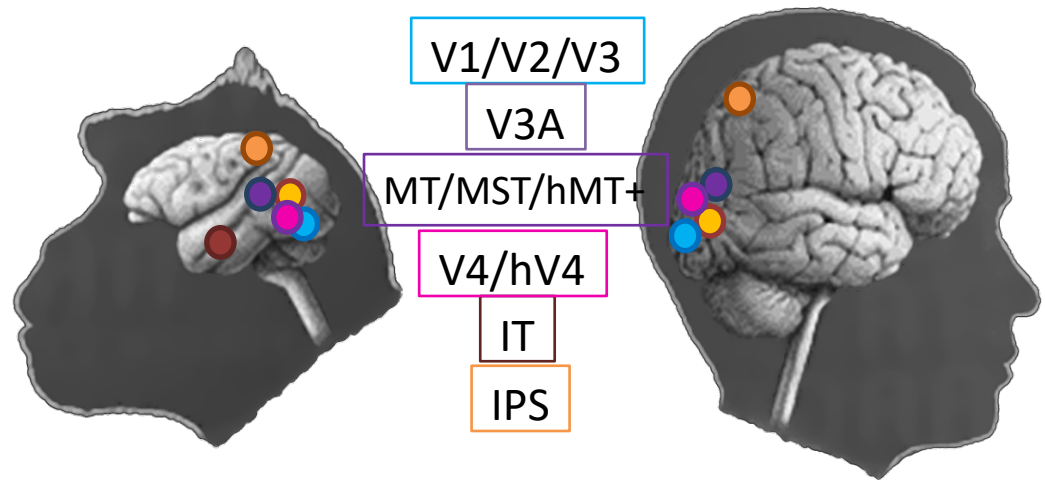


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E.g.: Hubel & Wiesel, 1970; DeAngelis et al., 1998; Janssen et al., 1999; Uka et al., 2000; Taira et al., 2000; Hinkle & Connor, 2001; Tsao et al., 2003; Durand et al., 2009;

Integration of disparity gradients

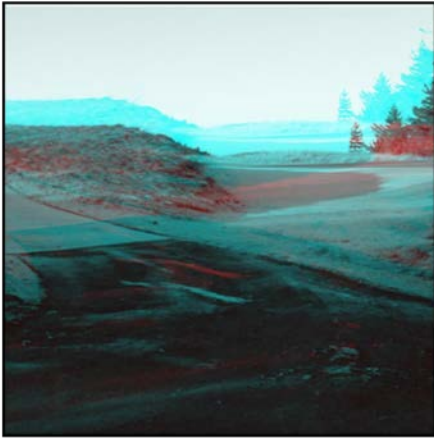
Spatial gradients



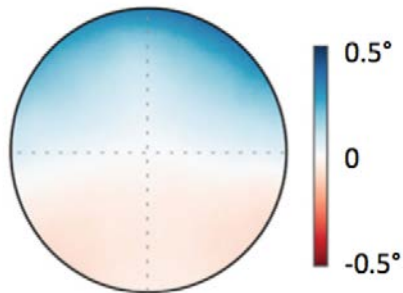
The brain network responding to spatial gradients is well known in macaques, so is the involvement of several human areas

What about an influence of natural statistics on spatial gradients processing?

Spatial gradients and statistical biases

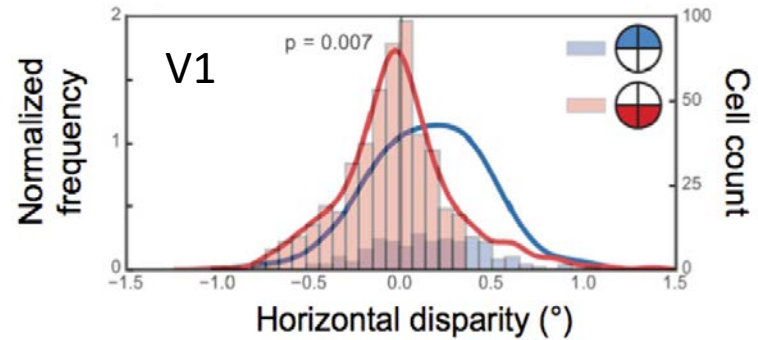
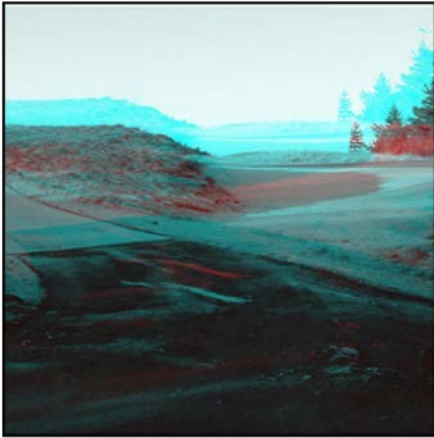


Horizontal disparity

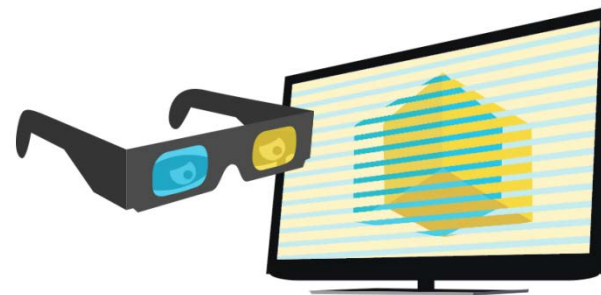
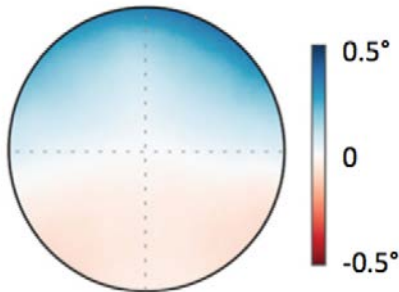


→ *Binocular disparities are not randomly distributed in natural scenes*

Spatial gradients and statistical biases



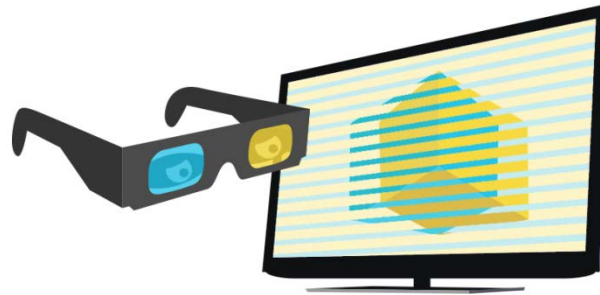
Horizontal disparity



→ *Binocular disparities are not randomly distributed in natural scenes*

Visual perception and natural statistics

Psychophysics
data - bias



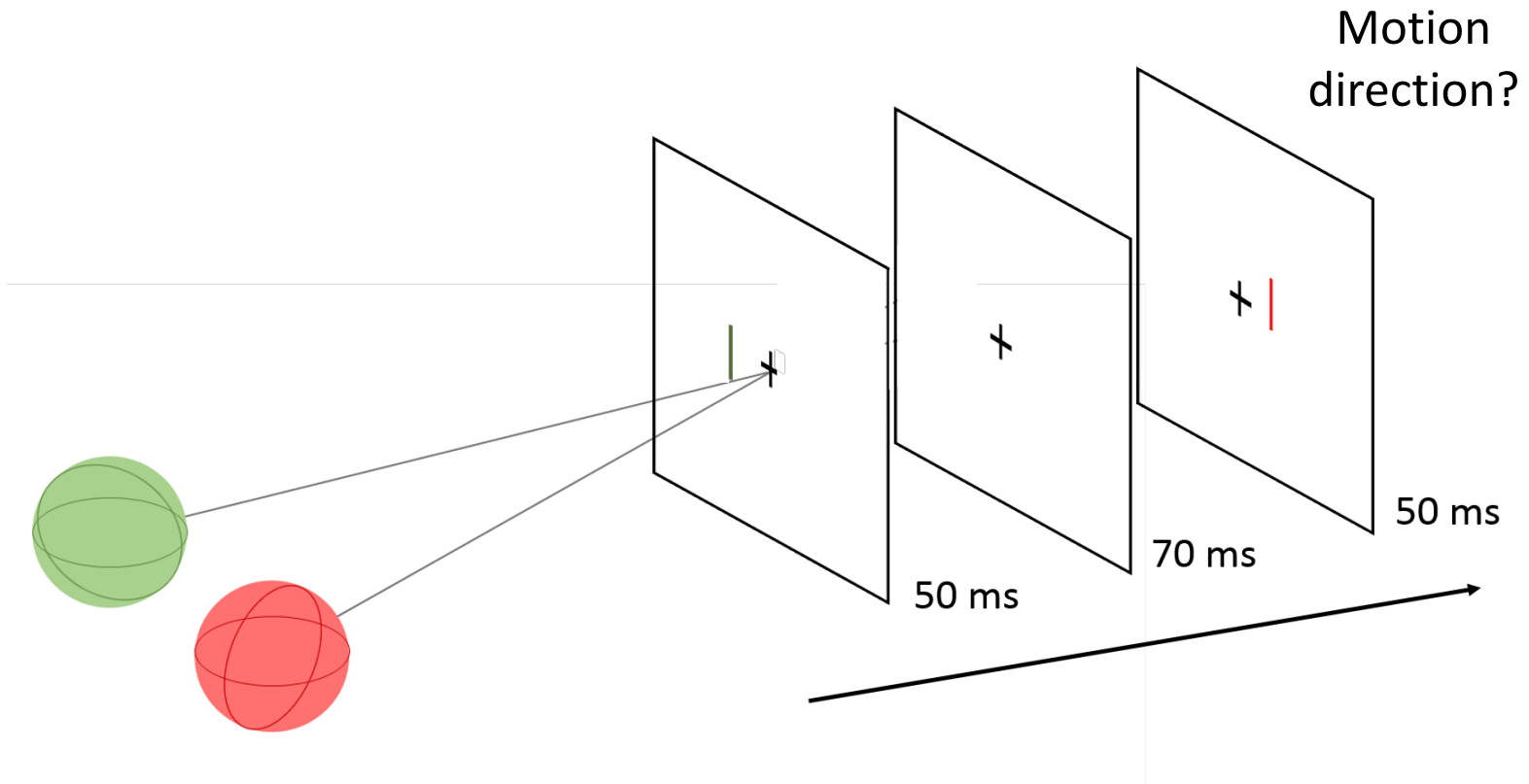
V1 neurons
- bias



Are statistical biases reflected at the level of visual perception in macaque?

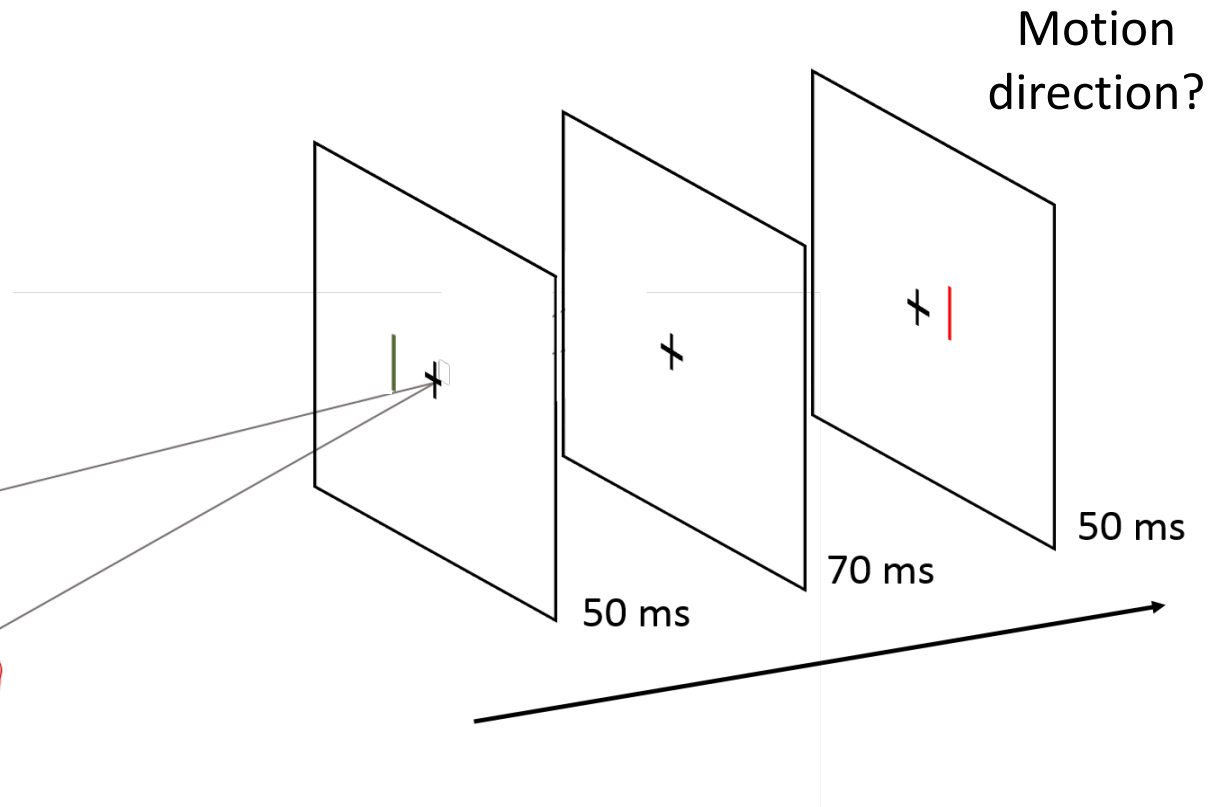
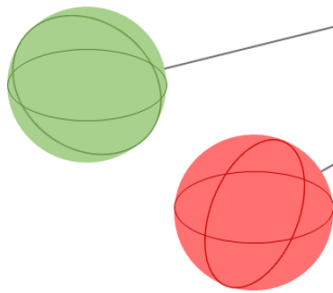
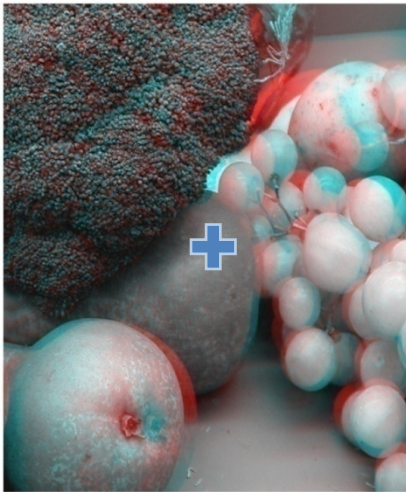
Measuring corresponding points

Experimental procedure adapted from Cooper E. et al., 2011

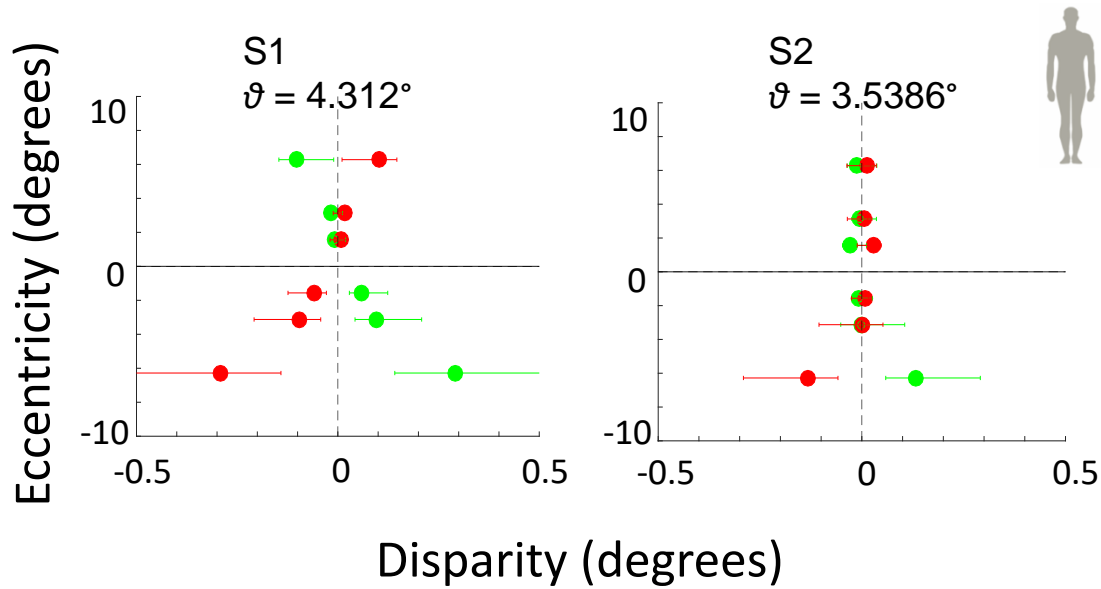


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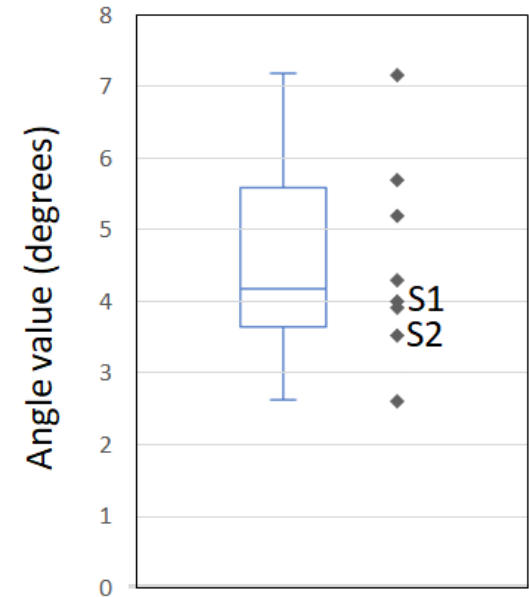
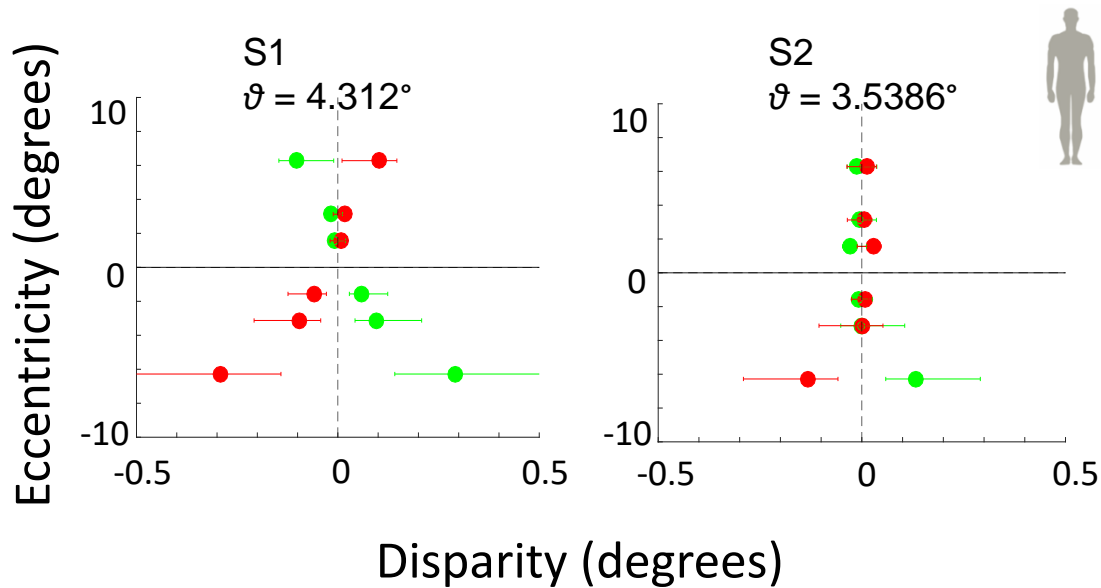
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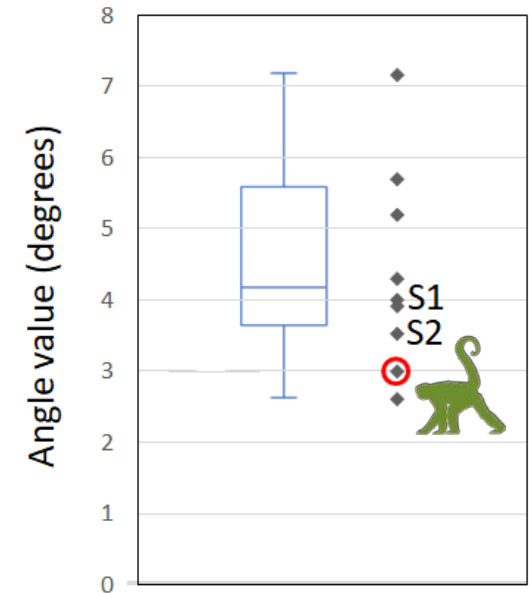
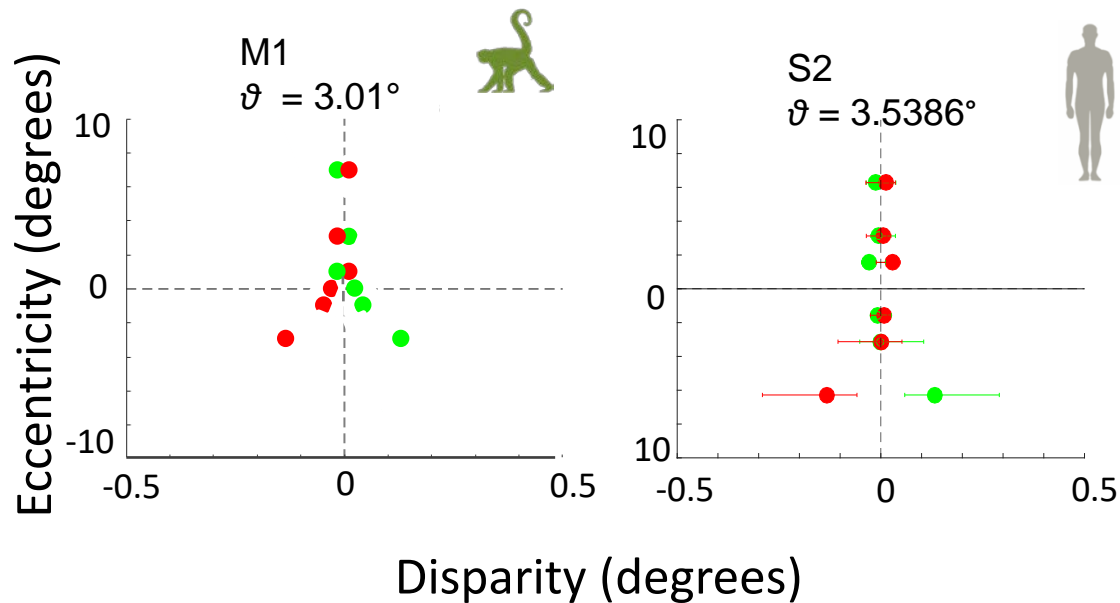
Corresponding points location



Corresponding points location



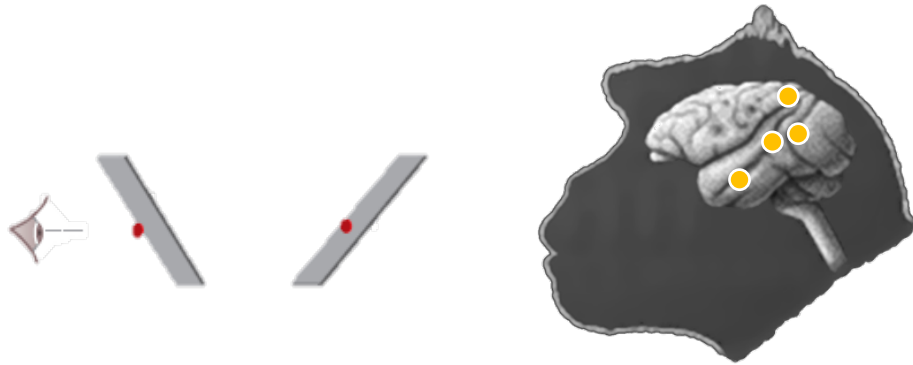
Corresponding points location



Successful adaptation of the experiment to one macaque subject with a tilt reflecting natural statistics

Related research work

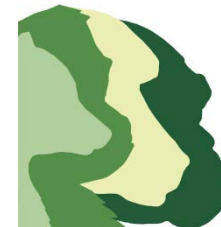
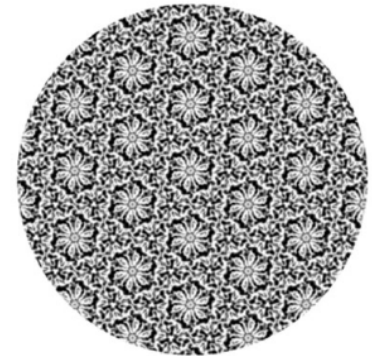
- Disparity gradients x natural statistics x fMRI
& Corresponding points experiment



Is there an influence of natural statistics within the cortical networks known to process binocular disparities ?

Related research work

- Disparity gradients x natural statistics x fMRI
& Corresponding points experiment
- Symmetry processing
Audurier, Héjja-Brichard et al., in prep
- Modelling binocular disparities
Chauhan, Héjja-Brichard, Cottureau, 2020
- Optic flow (fMRI & connectivity)
Cottureau et al., 2017; De Castro et al., 2020
- ManyPrimates: Large-scale collaboration
- COS Ambassador: Open x Slow science



Thank you for your attention!

