

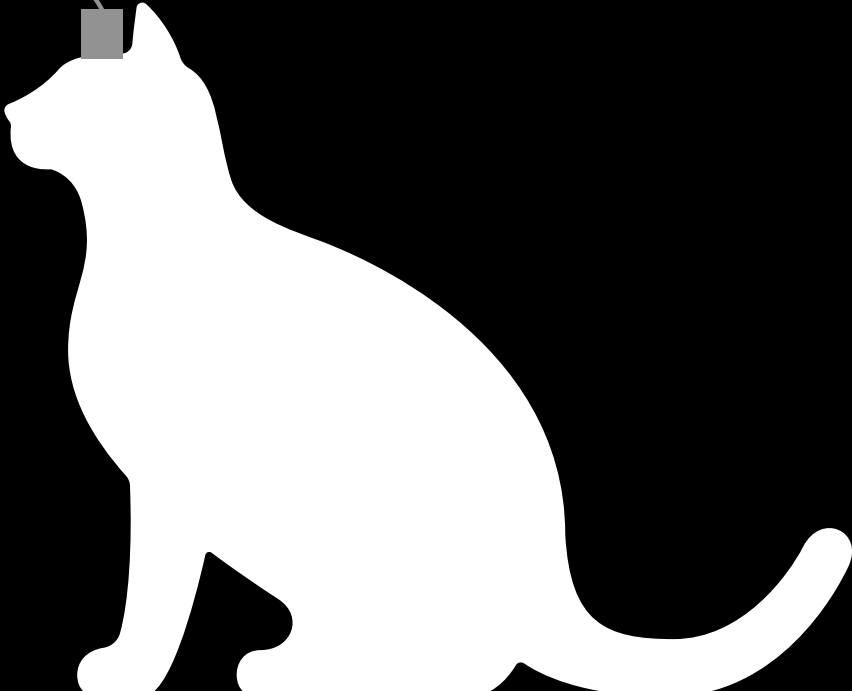
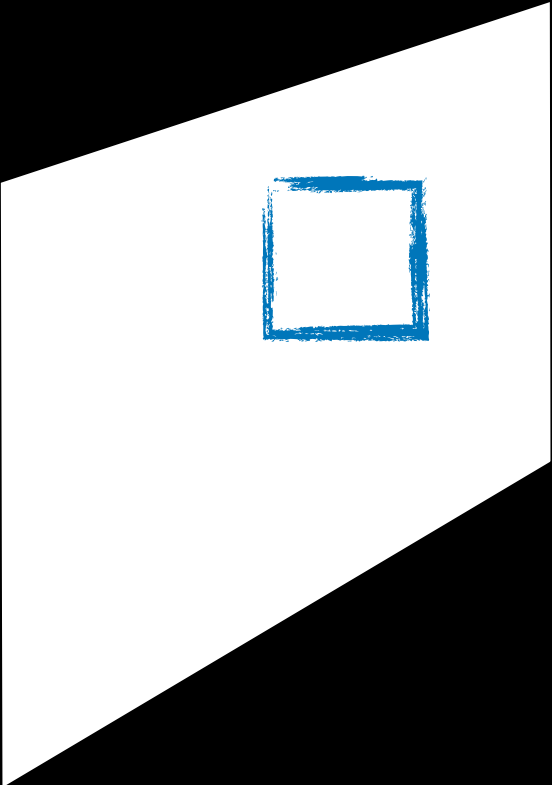
# High-level vision



Enters area of blue square



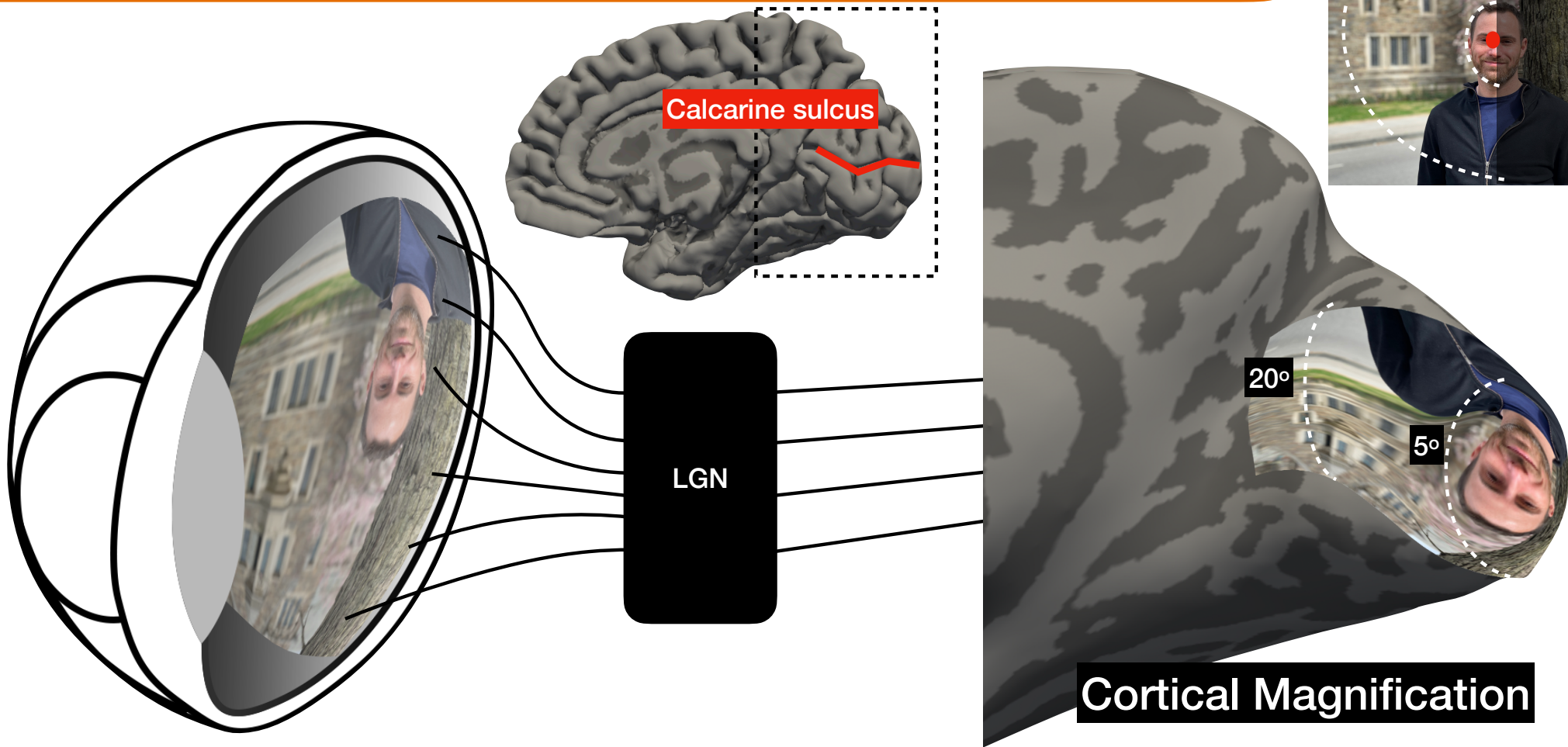
Trial 1  
Trial 2  
Trial 3



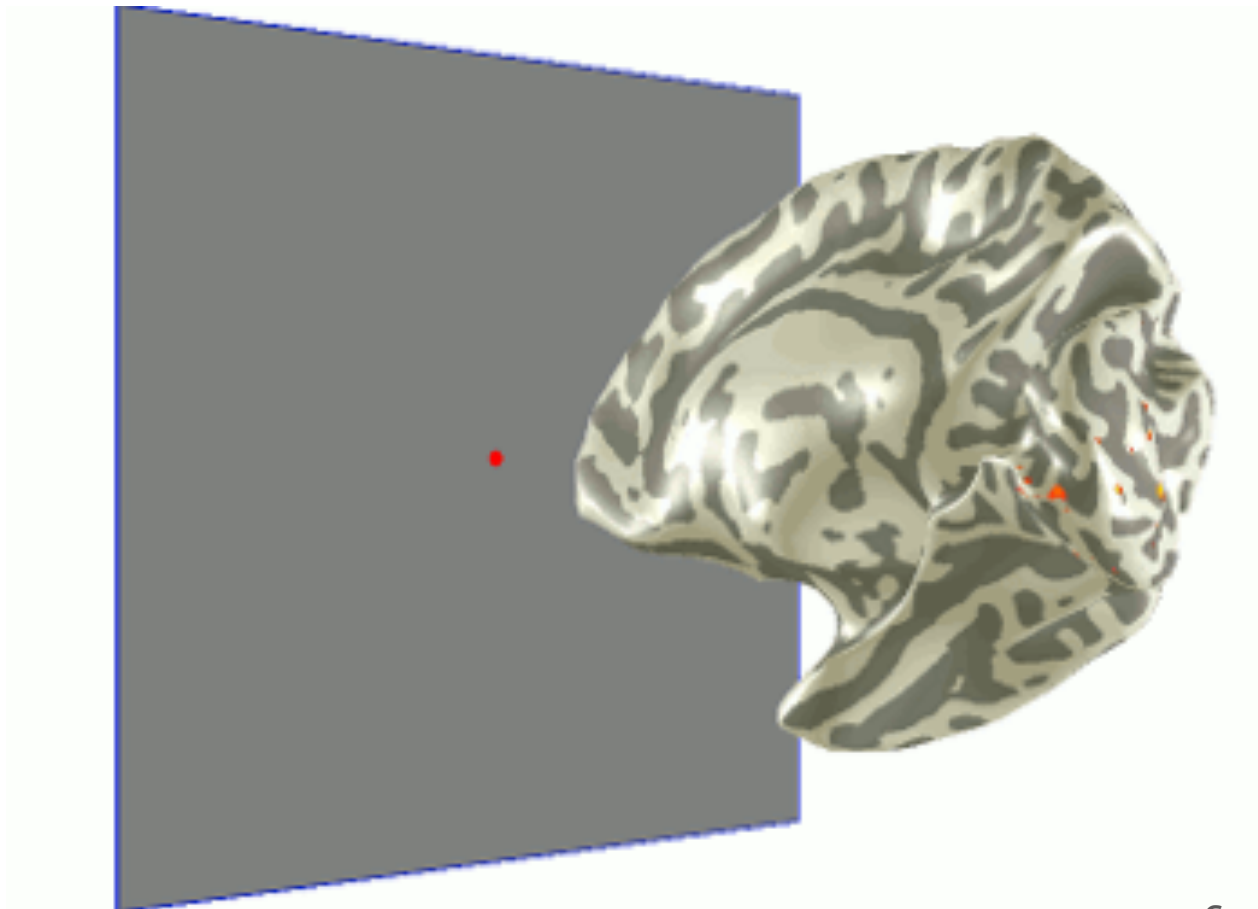
Hubel & Wiesel experiments, 1962



# Visual cortex is organized retinotopically

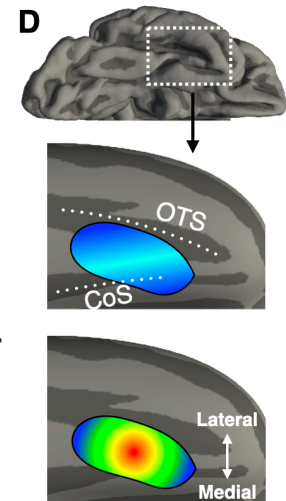
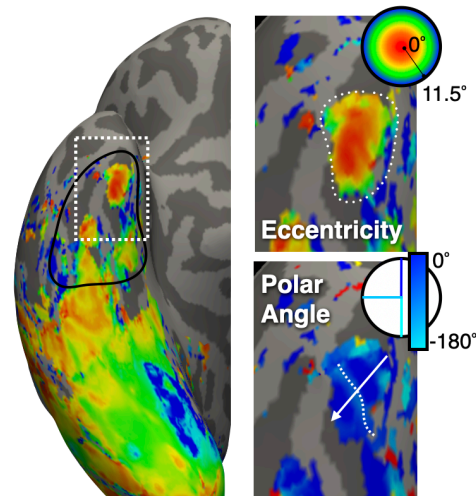
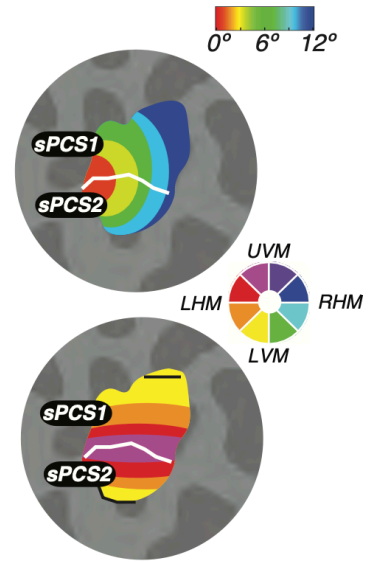
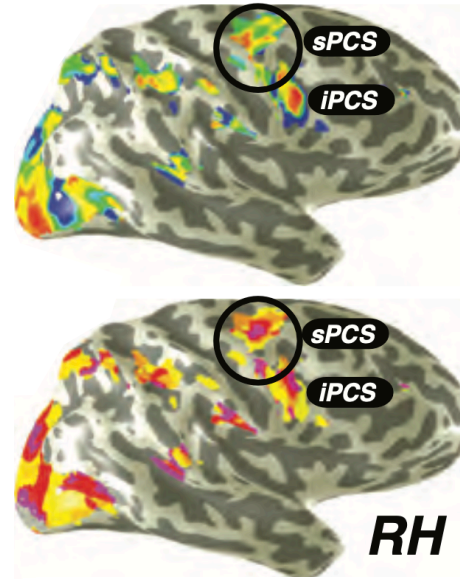


# Measuring population receptive fields in human visual cortex

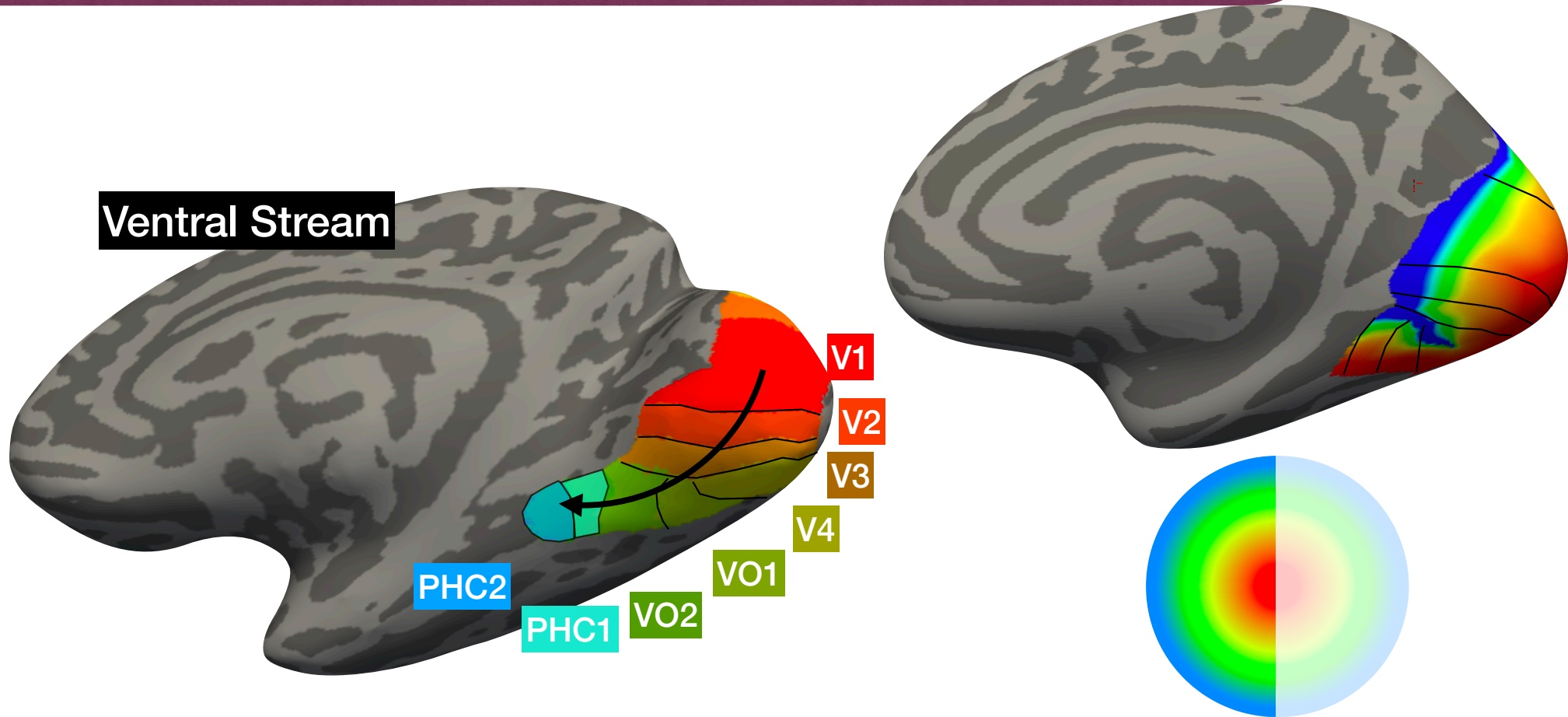


Courtesy the Wandell Lab

- hFEF
- SPL1
- IPS5
- IPS4
- IPS3
- IPS2
- IPS1
- IPS0
- TO2
- TO1
- LO2
- LO1
- V3b
- V3a
- V3d
- V2d
- V1d
- V1v
- V2v
- V3v
- hV4
- VO1
- VO2
- PHC1
- PHC2



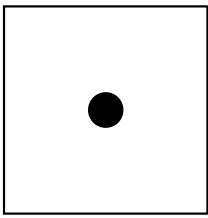
# Object recognition begins in visual cortex



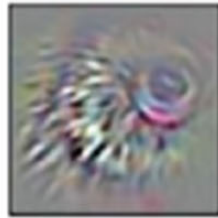
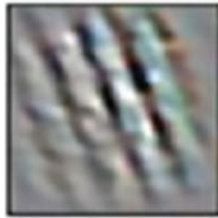


# Increasingly complex representations along ventral stream

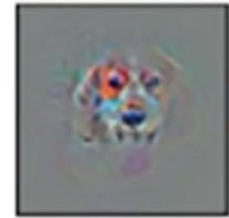
Retina



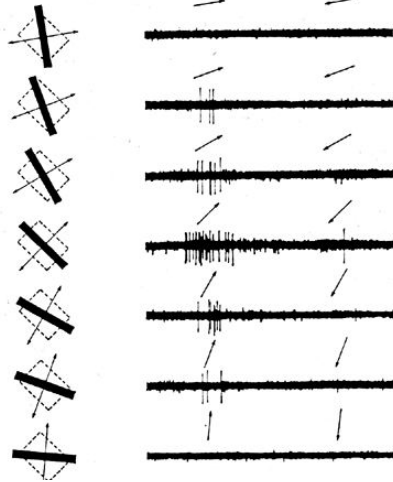
V1



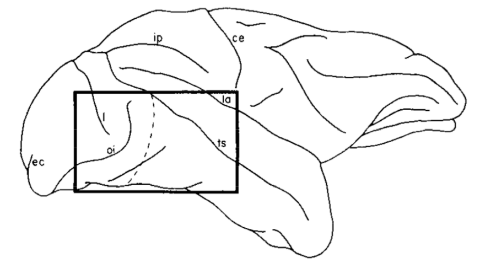
VTC  
ventral temporal cortex



Hubel & Wiesel 1962



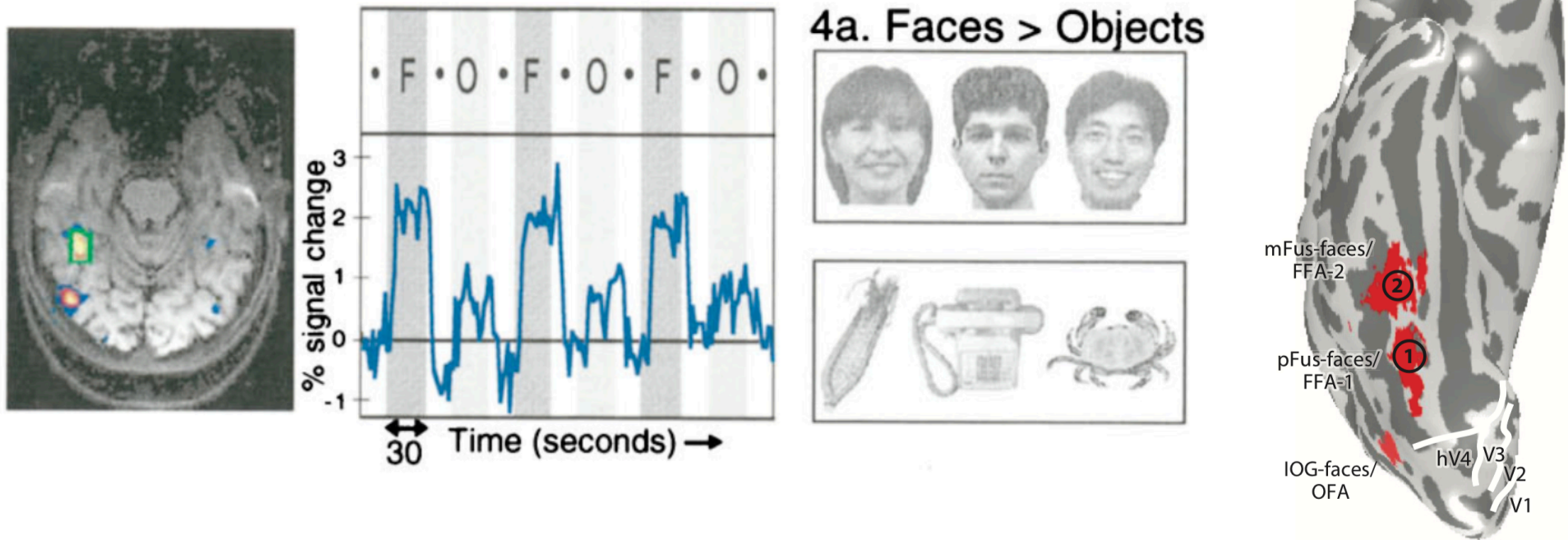
Gross et al. 1969; 1979



## The "localizer" approach in visual cognitive neuroscience



# fMRI used to 'localize' specialized brain regions

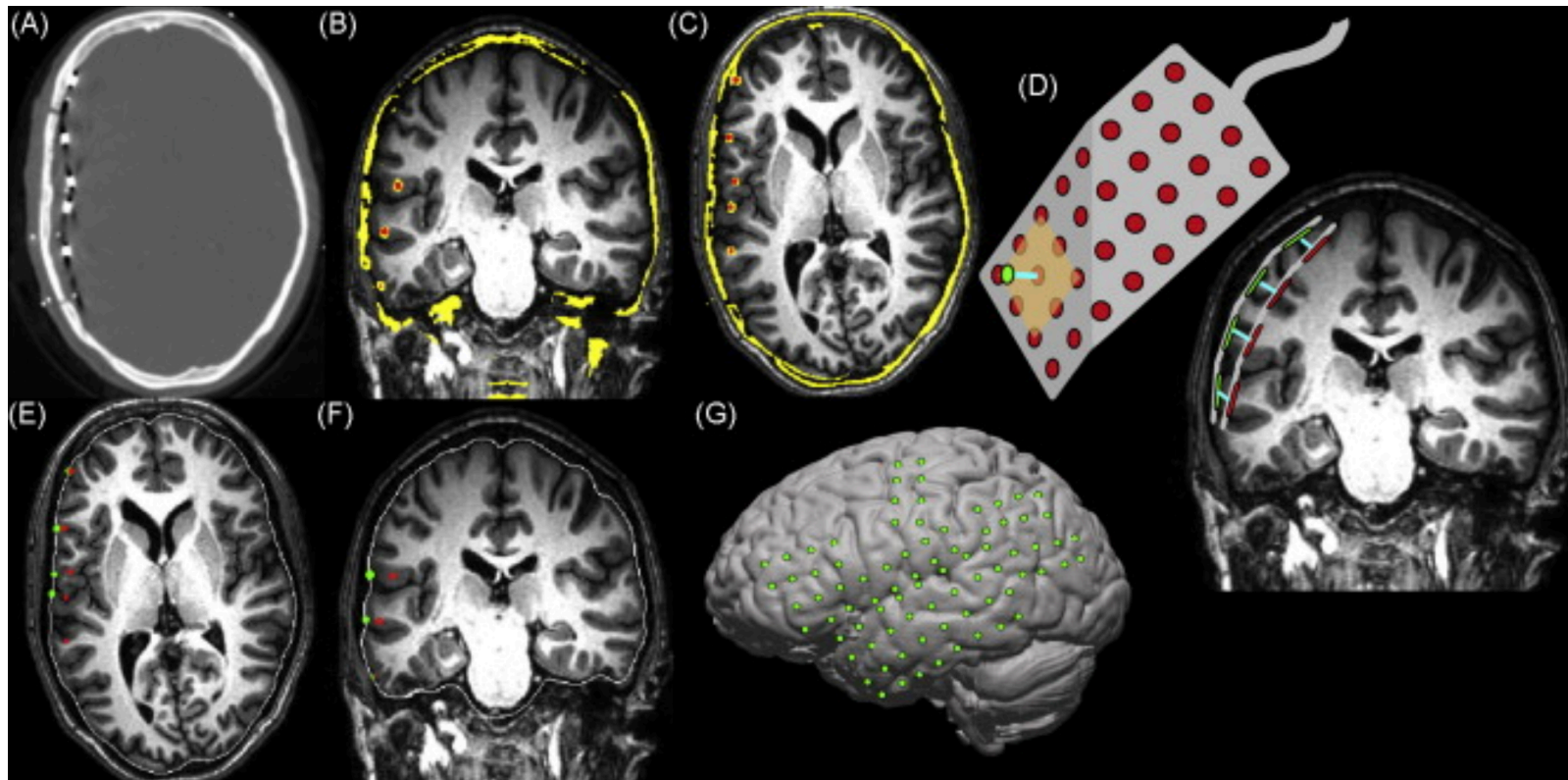


Kanwisher et al. 1997; Allison et al. 1994

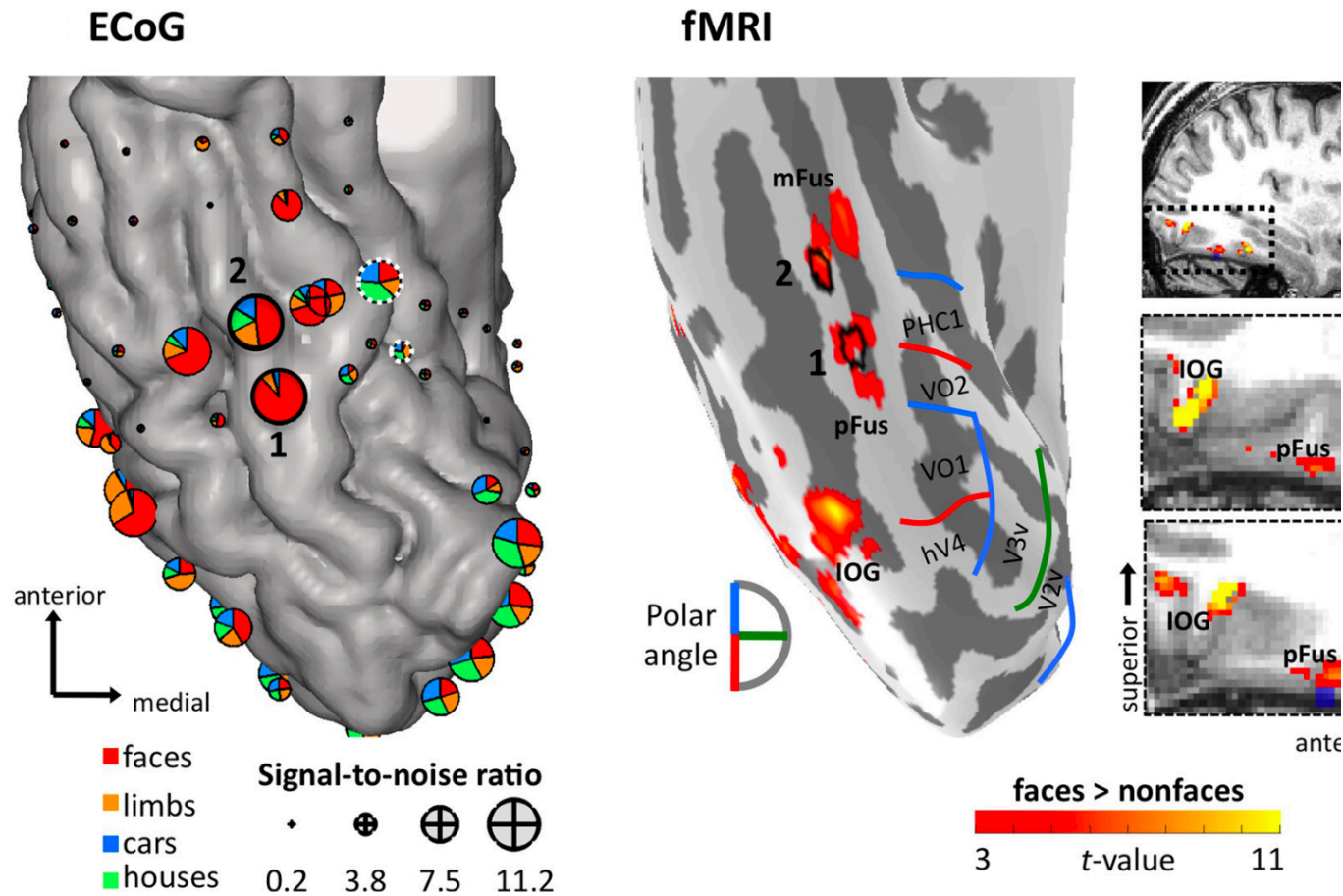
Weiner & Grill-Spector 2012 *TICS*



# Testing the causality of ventral neural representations

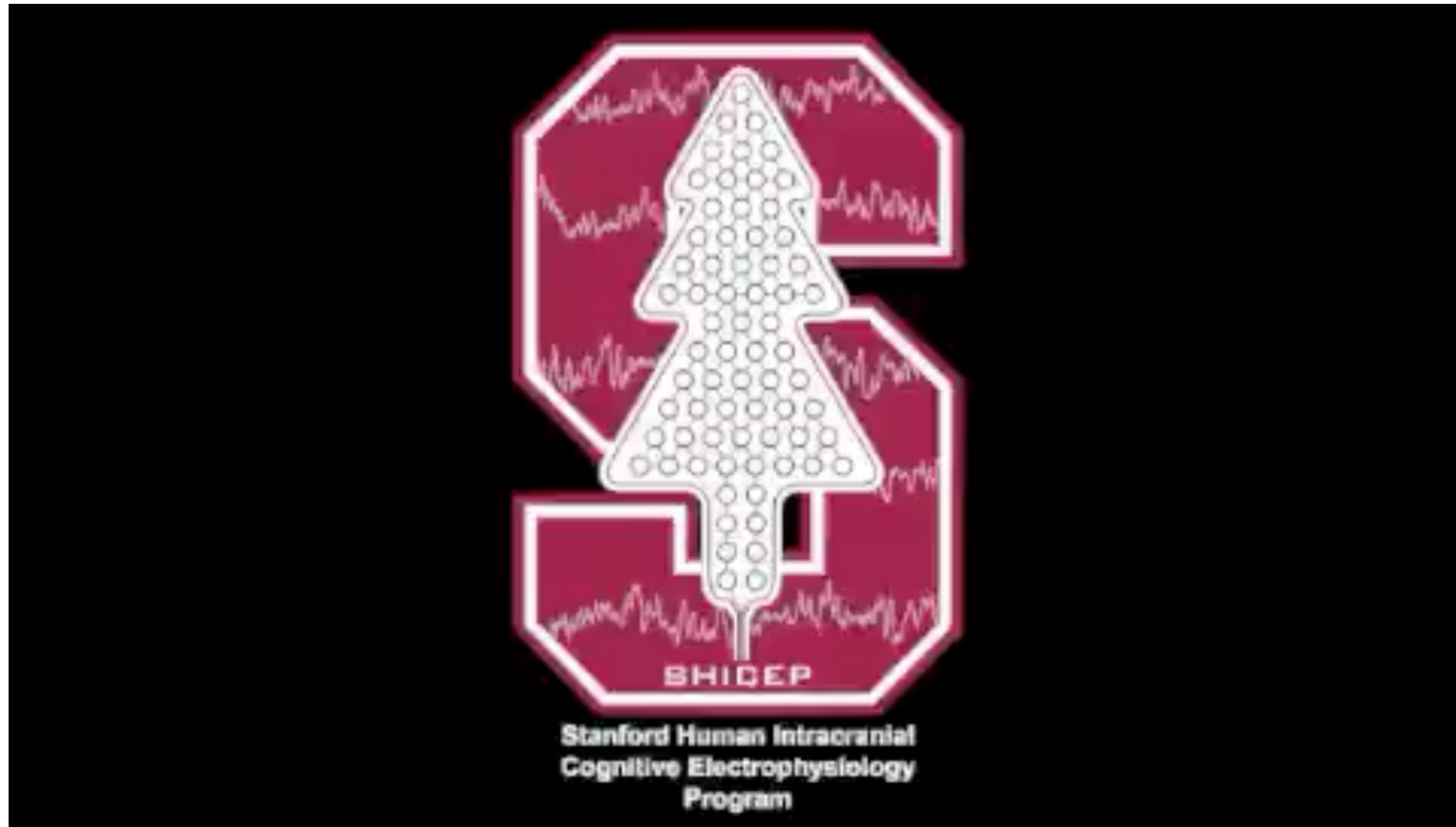


# Testing the causality of ventral neural representations



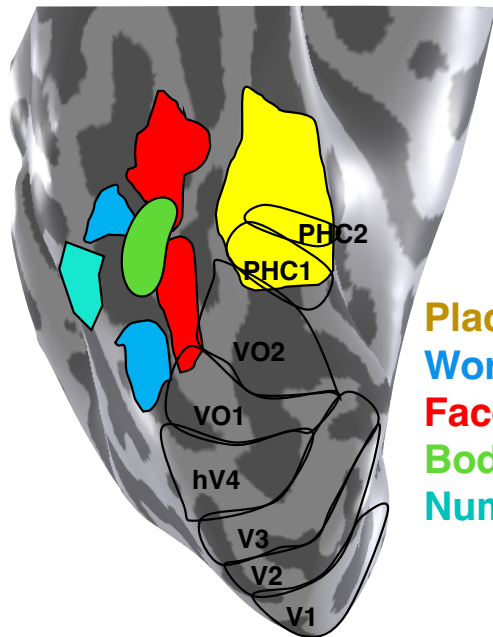
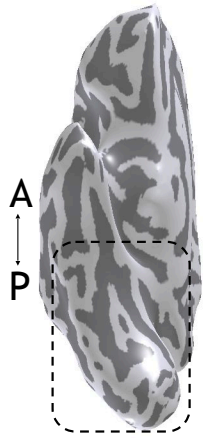
Parvizi et al., 2012 J. Neurosci.

# ECoG enables causal manipulation through brain stimulation



Parvizi et al., 2012 J. Neurosci.

# Category-selectivity for faces, words, bodies, places, numbers



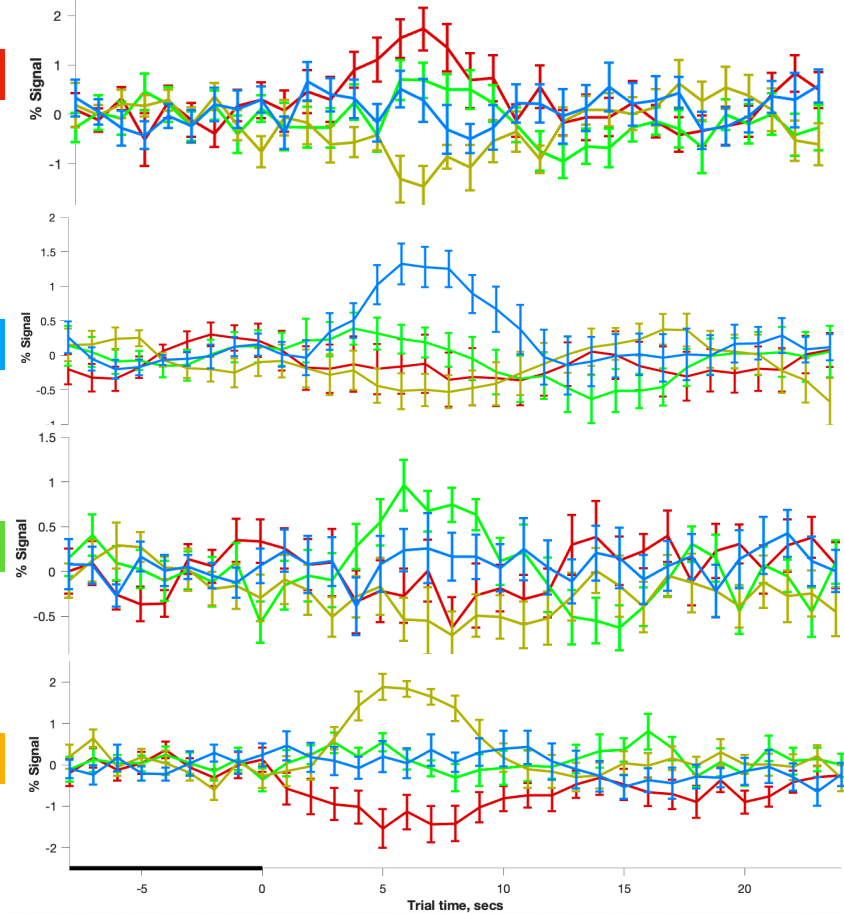
Places  
Words  
Faces  
Bodies/Limbs  
Numbers

OTS-bodies

FFA-1

VWFA-1

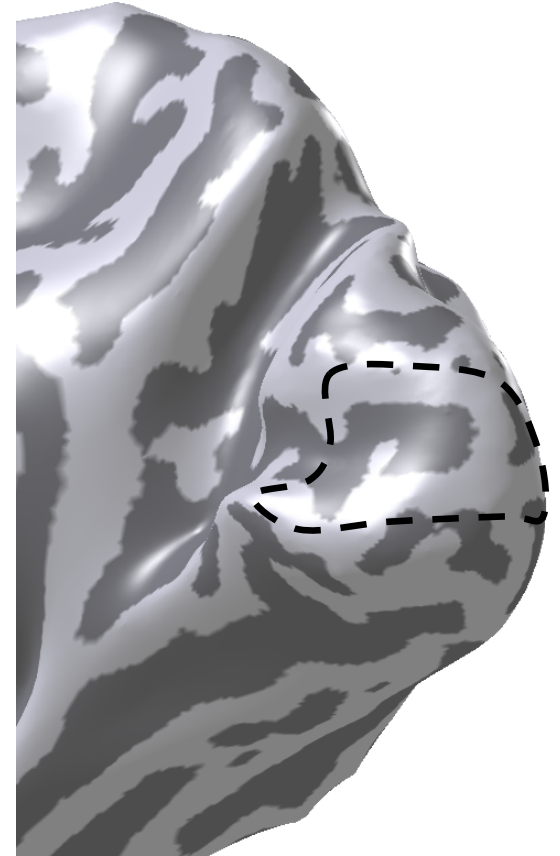
PPA



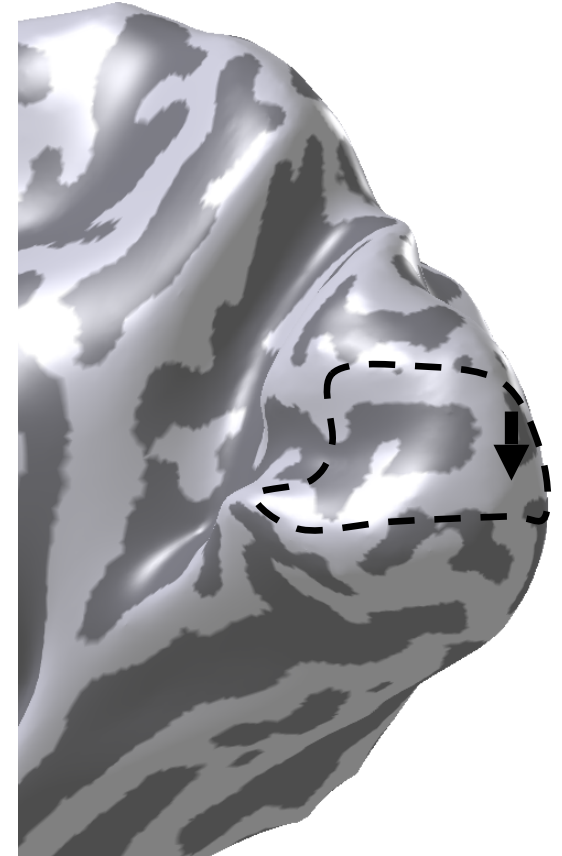
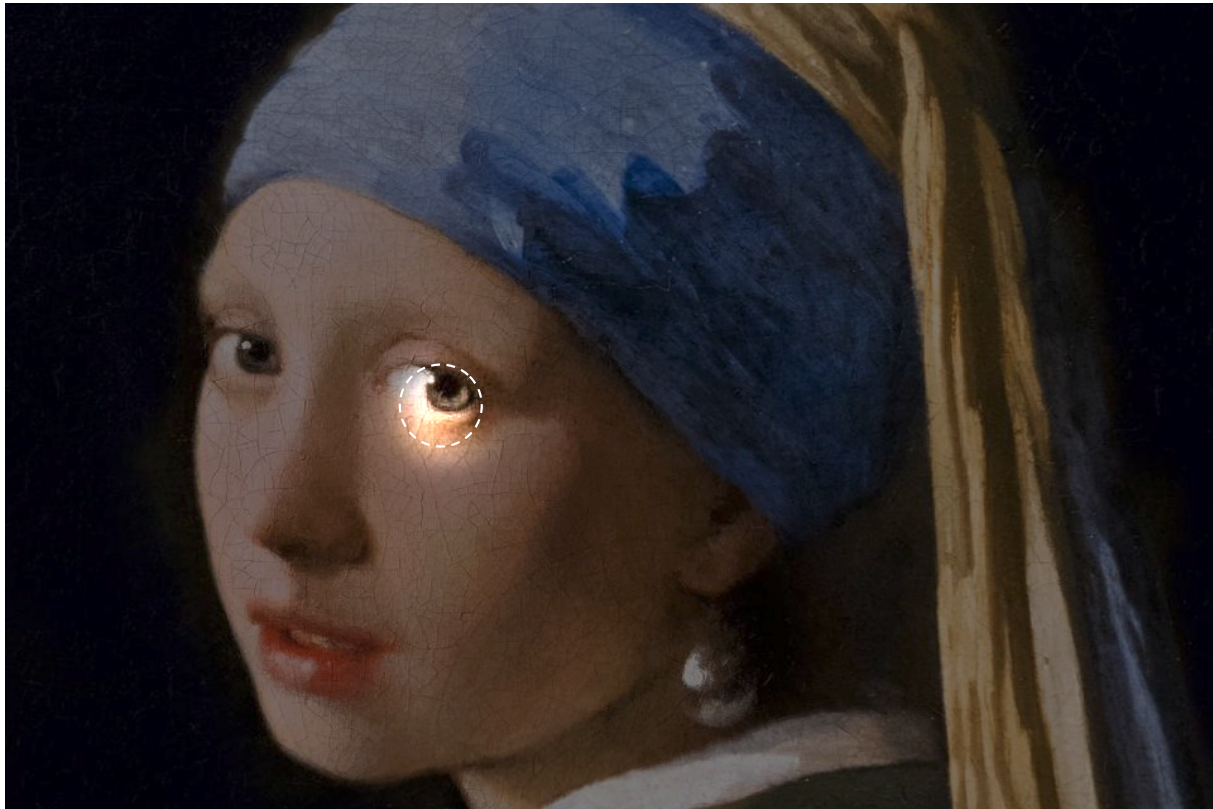
- Kanwisher 1997
- Epstein 1998
- Cohen 2000
- Peelen 2005
- Golarai et al., 2007
- Scherf et al., 2007
- Ben-Shachar et al., 2011
- Cantlon et al., 2010
- Lambert-Dehaene et al., 2018
- Gomez et al., 2018ab



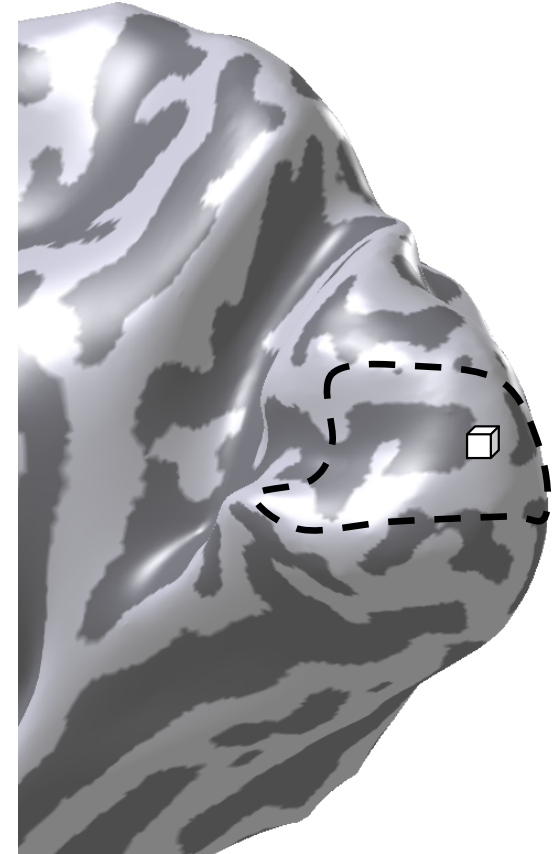
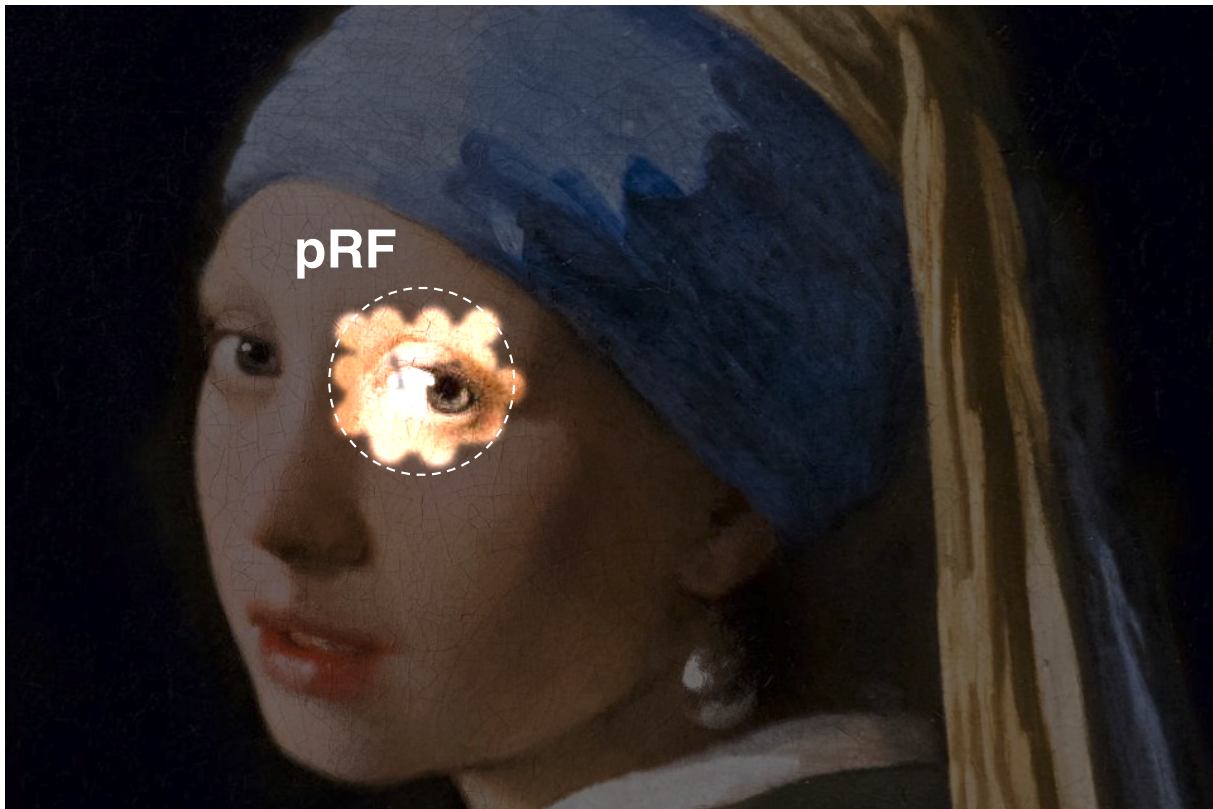
## Measuring population receptive fields in human visual cortex



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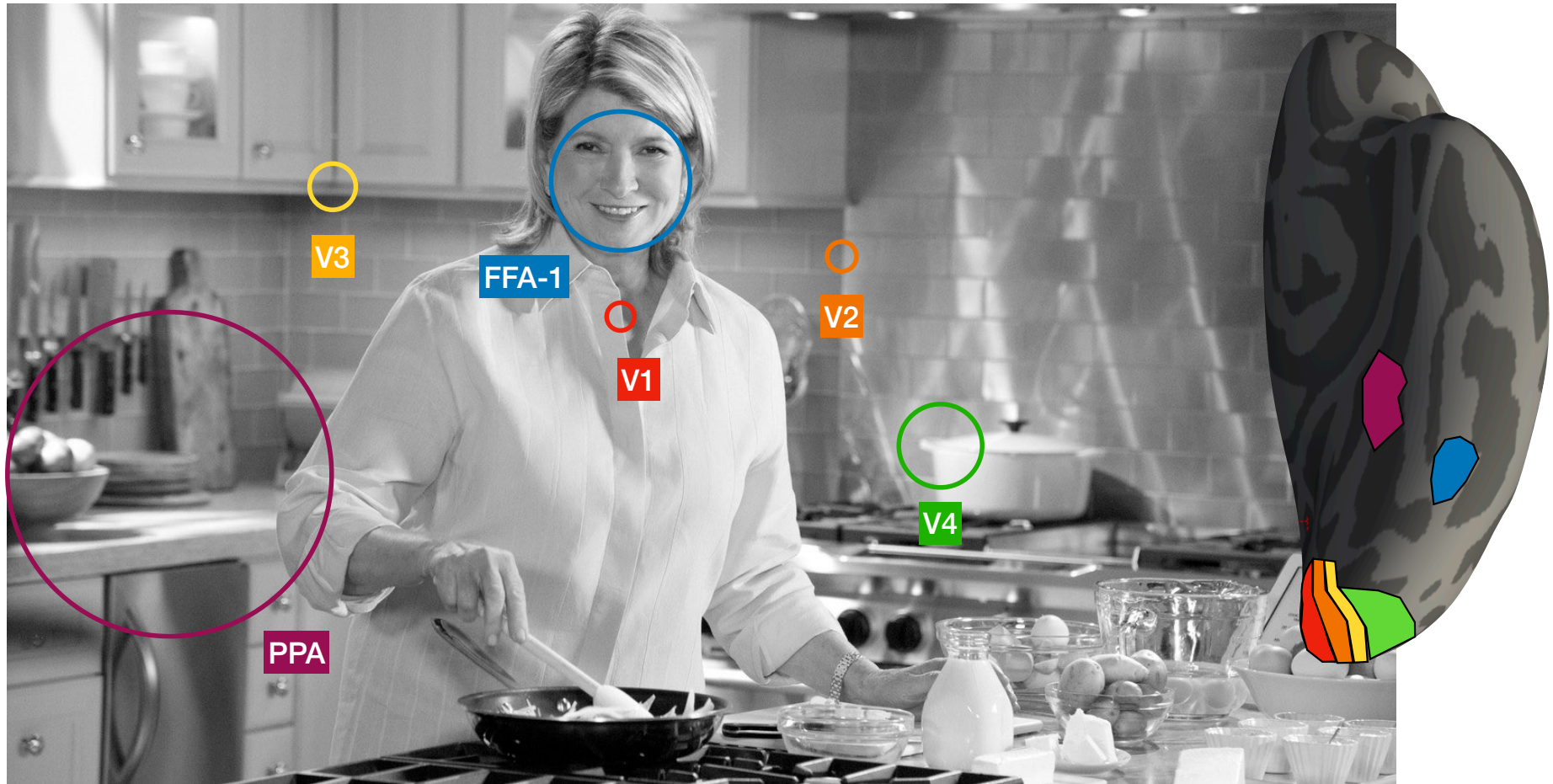




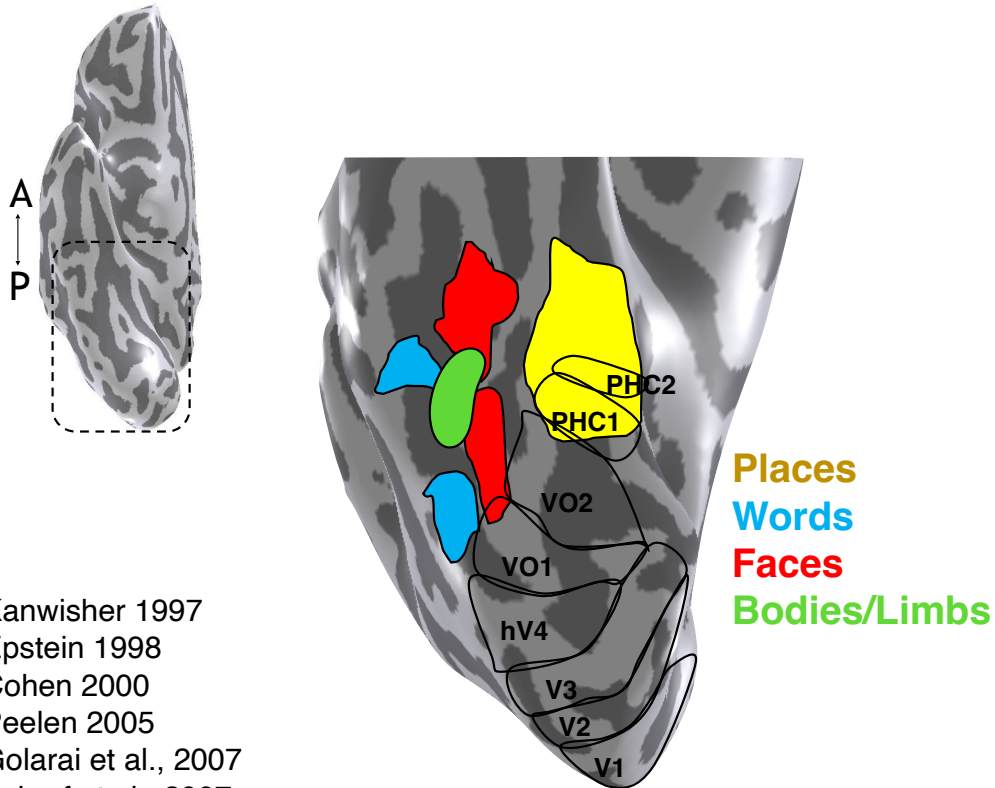
# High-level visual neurons pool input from many neurons



# High-level visual neurons pool input from many neurons



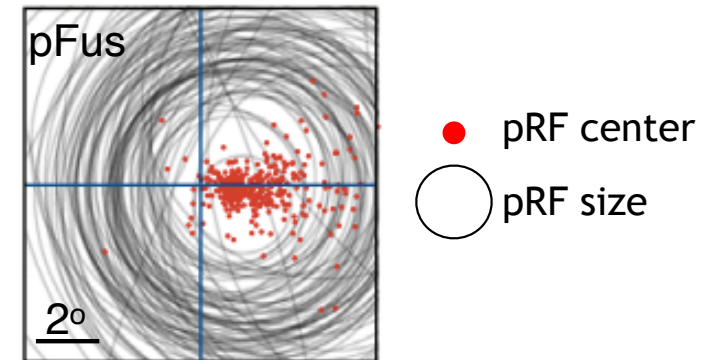
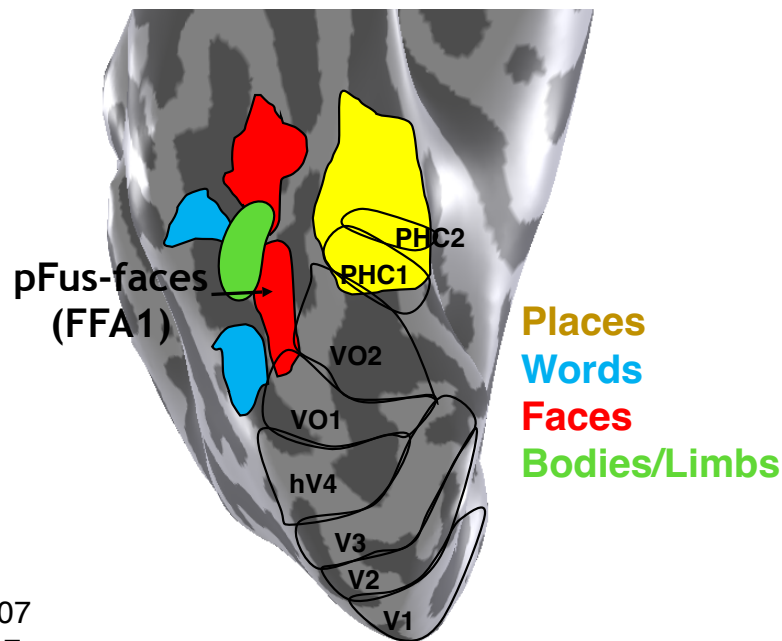
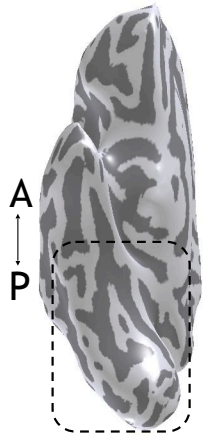
## pRFs are also prevalent in high-level visual regions



Kanwisher 1997  
Epstein 1998  
Cohen 2000  
Peelen 2005  
Golarai et al., 2007  
Scherf et al., 2007  
Ben-Shachar et al., 2011  
Cantlon et al., 2010  
Lambert-Dehaene et al., 2018  
Gomez et al., 2018ab



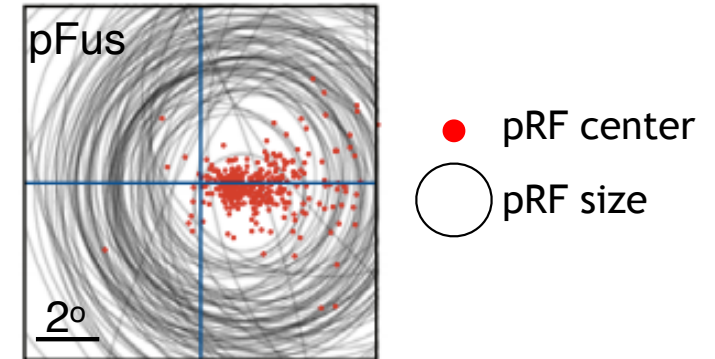
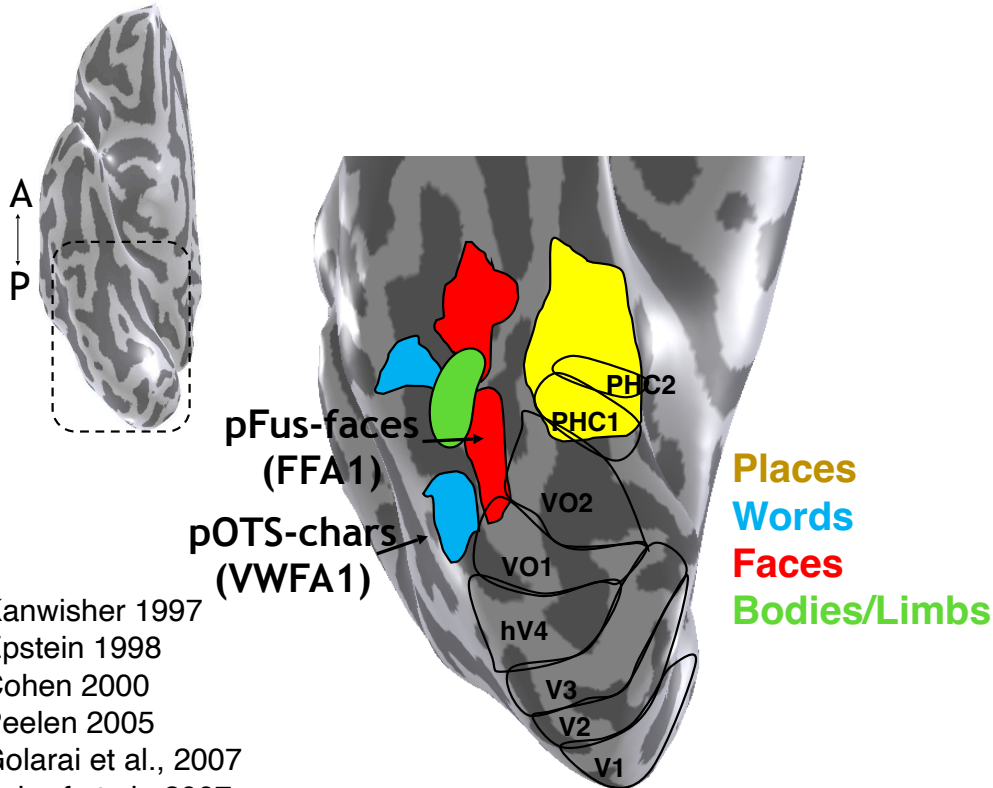
# pRF mapping reveals retinotopy is a fundamental encoding principle



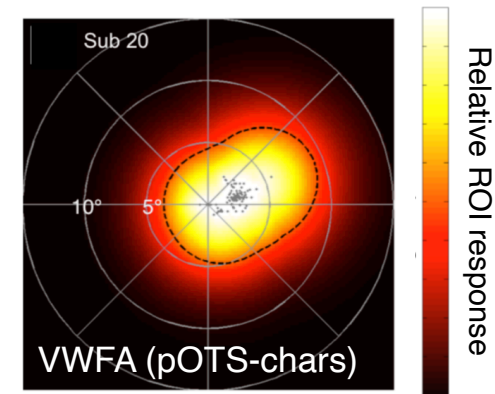
Kay, Weiner, Grill-Spector 2015

- Kanwisher 1997
- Epstein 1998
- Cohen 2000
- Peelen 2005
- Golarai et al., 2007
- Scherf et al., 2007
- Ben-Shachar et al., 2011
- Cantlon et al., 2010
- Lambert-Dehaene et al., 2018
- Gomez et al., 2018ab

# pRF mapping reveals retinotopy is a fundamental encoding principle



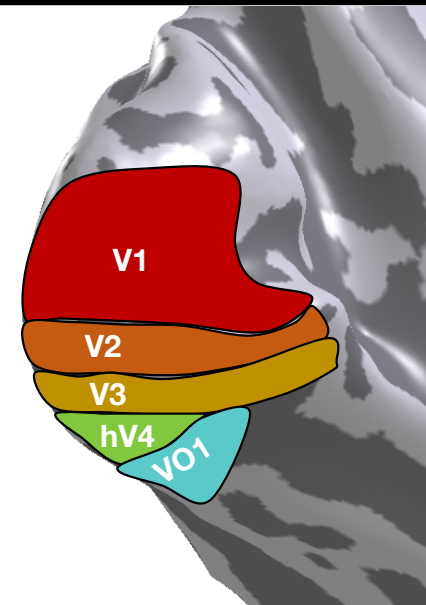
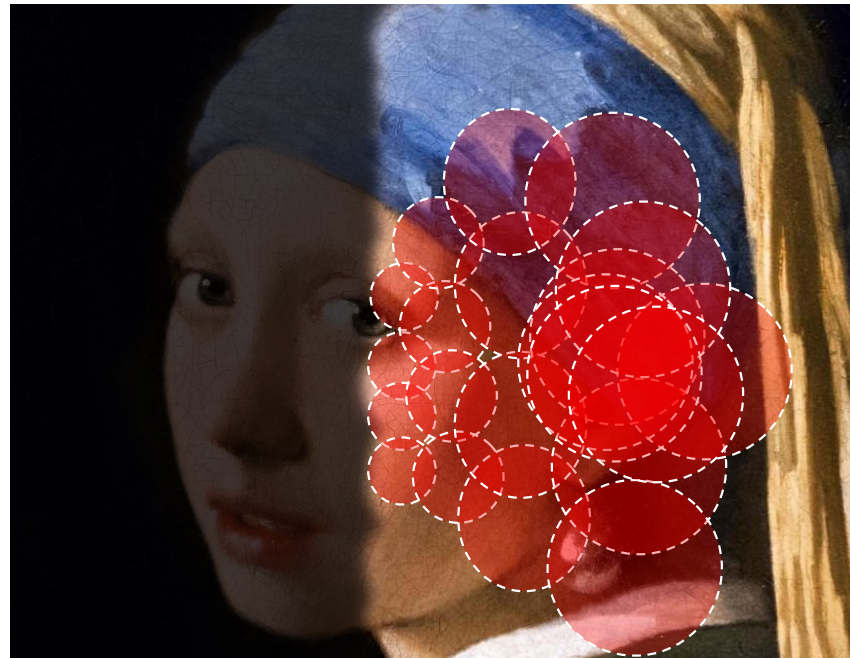
Kay, Weiner, Grill-Spector 2015



Le, Witthoft, Ben-Shachar, Wandell 2016

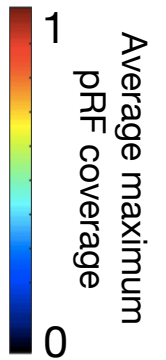
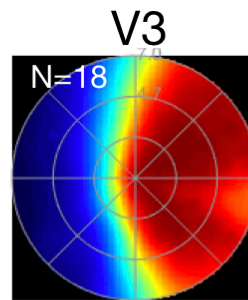
- Kanwisher 1997
- Epstein 1998
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- Peelen 2005
- Golarai et al., 2007
- Scherf et al., 2007
- Ben-Shachar et al., 2011
- Cantlon et al., 2010
- Lambert-Dehaene et al., 2018
- Gomez et al., 2018ab

**Visual field coverage is stable from childhood to adulthood in early maps**



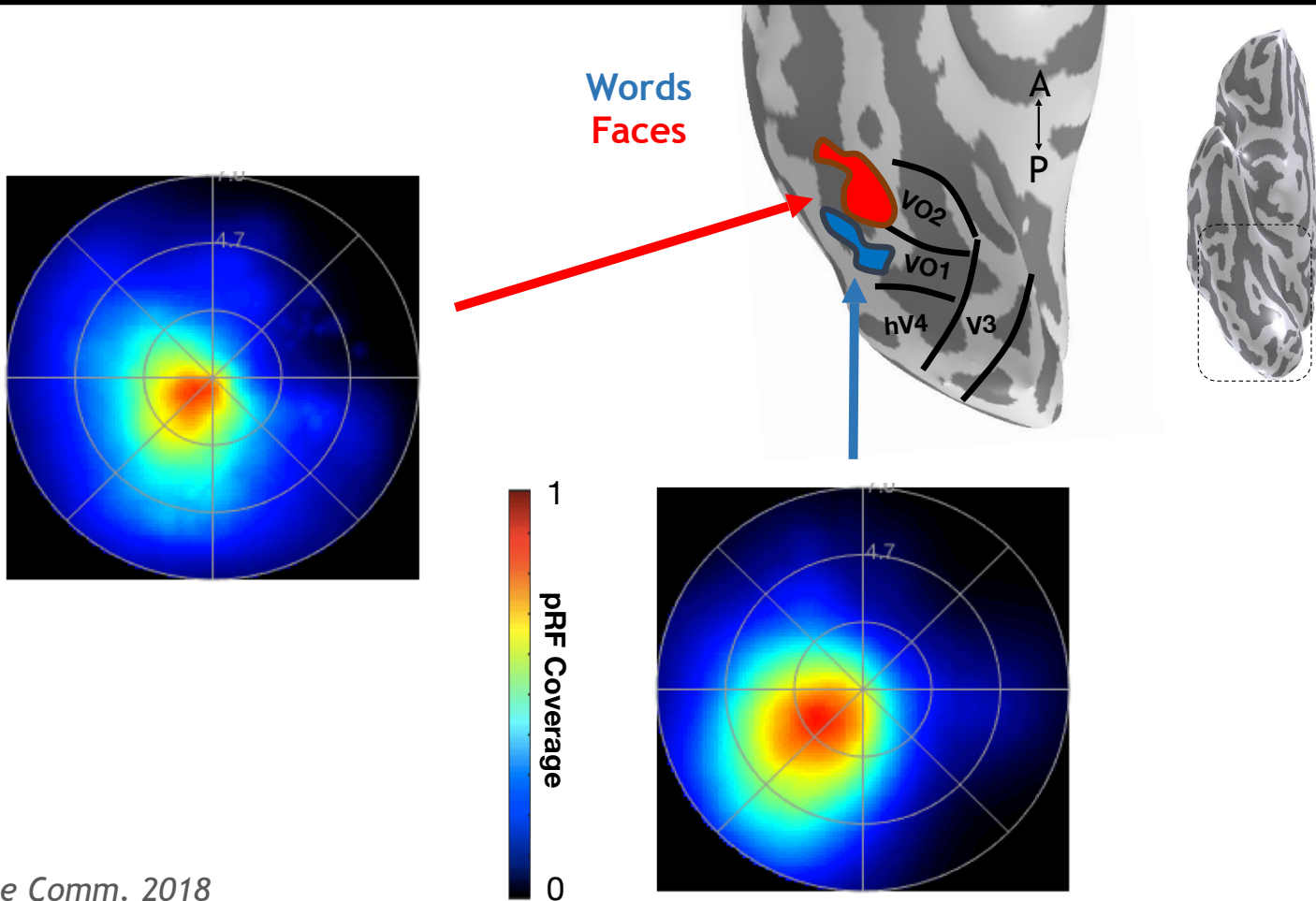
# Visual field coverage is stable from childhood to adulthood in early maps

## Left Hemisphere

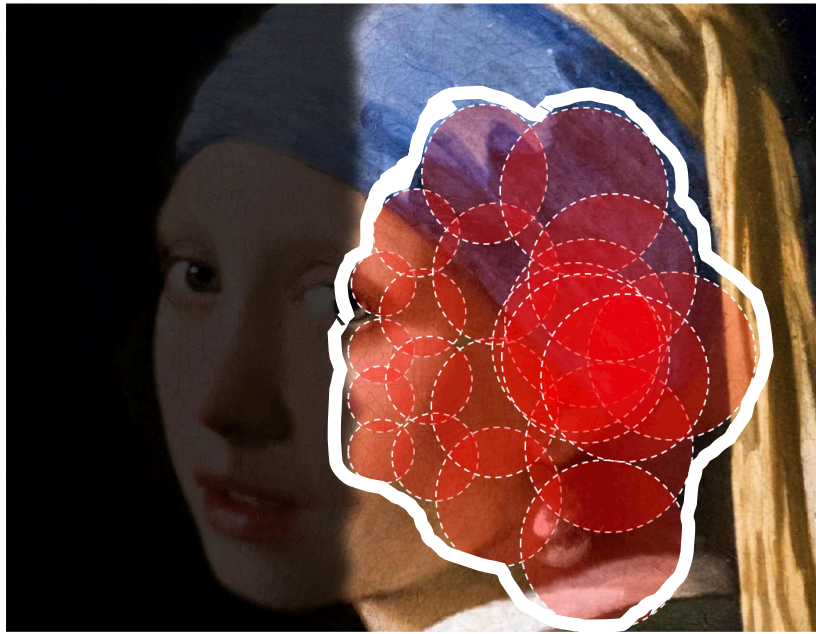




# pRF coverage develops differently across hemispheres in face/word regions

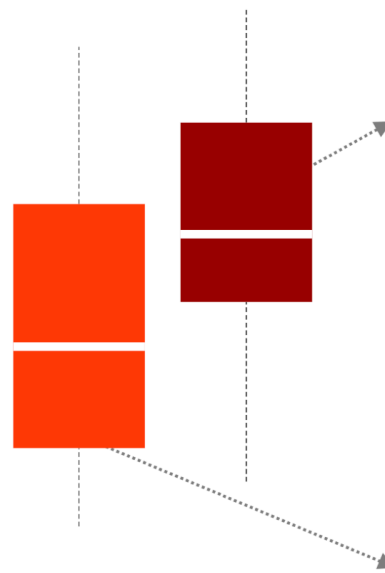


# Developmental increases in pRF coverage of the face and word regions



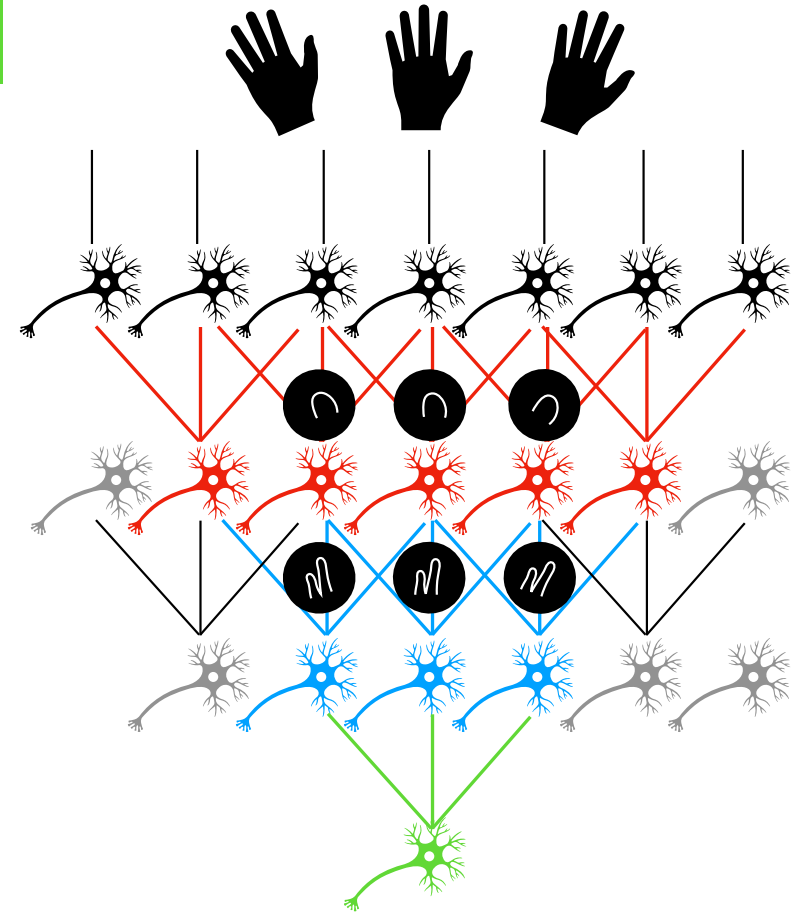
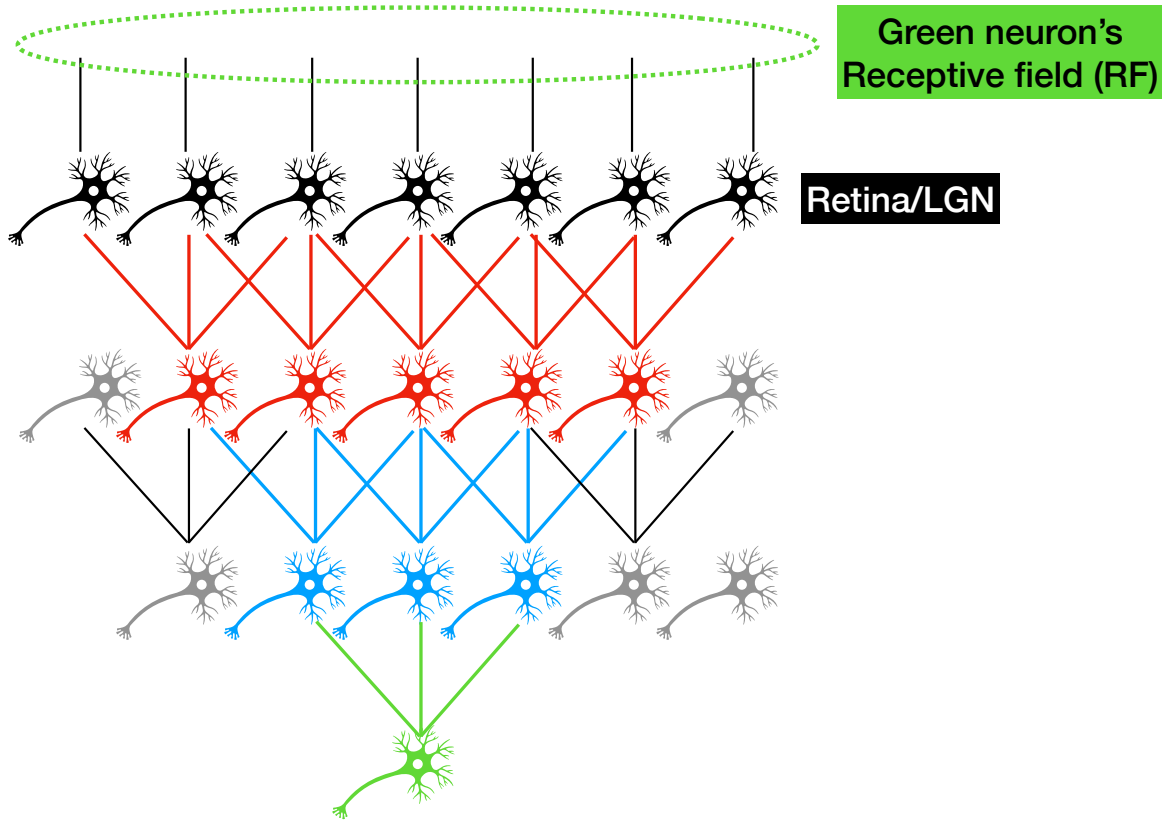
0 |

Child Adult  
**pOTS-words**



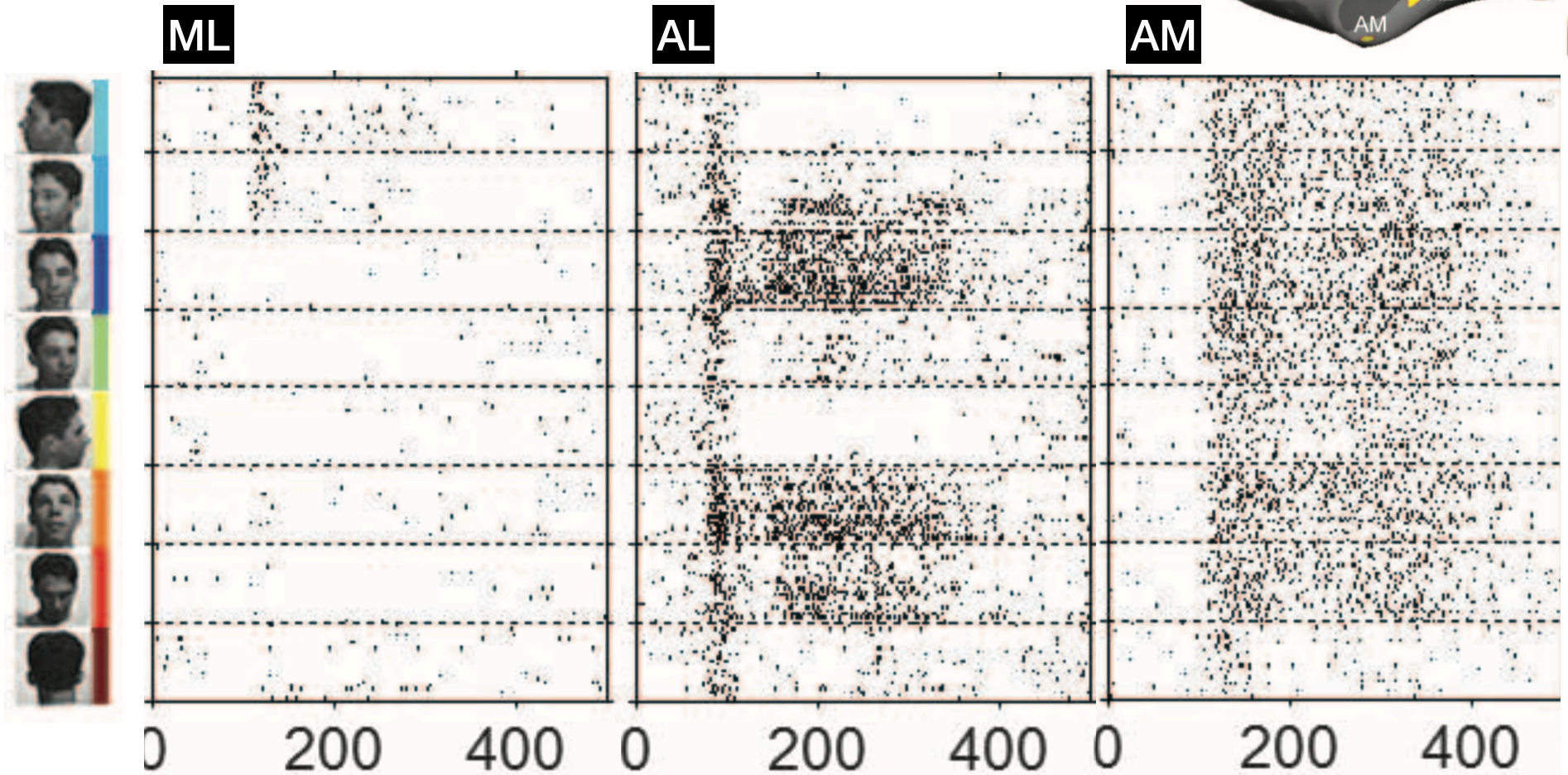
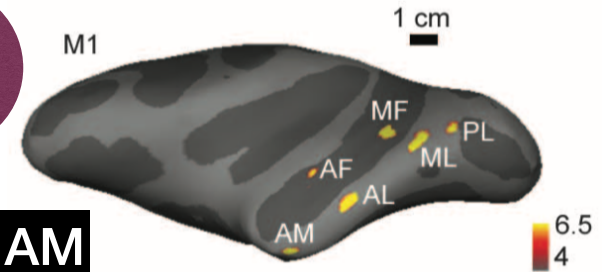
Child Adult  
**pFus-faces**

# Spatial pooling increases the invariance of responses



# Ascending the face network reveals increasingly invariant representations

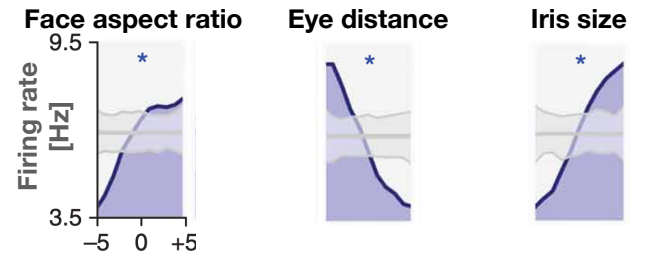
Freiwald & Tsao 2010 *Science*



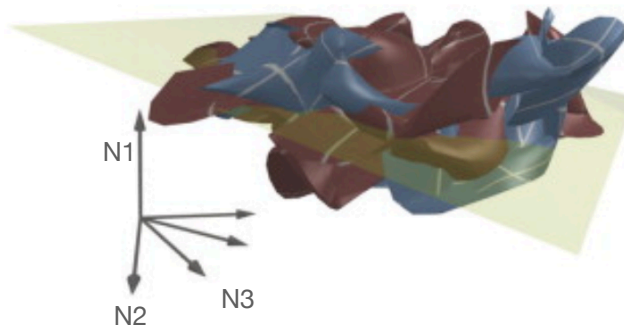


# Computationally, the ventral stream “untangles” representations of objects

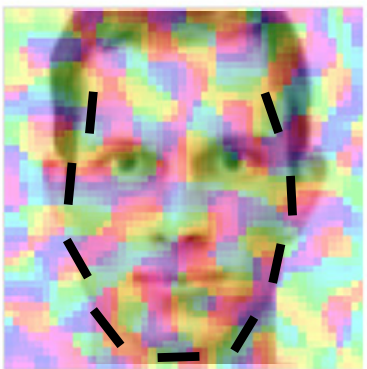
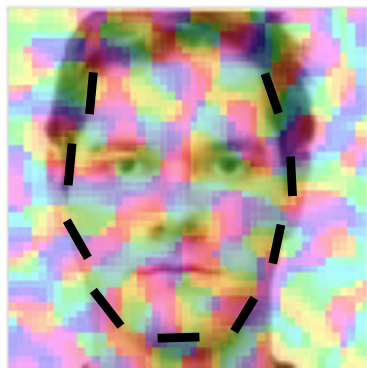
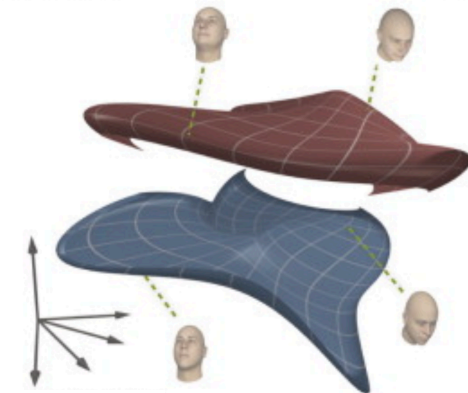
Freiwald, Tsao, Livingstone  
2009 *NatNeuro*



High dimensional neural representation of two faces in V1 will be very similar

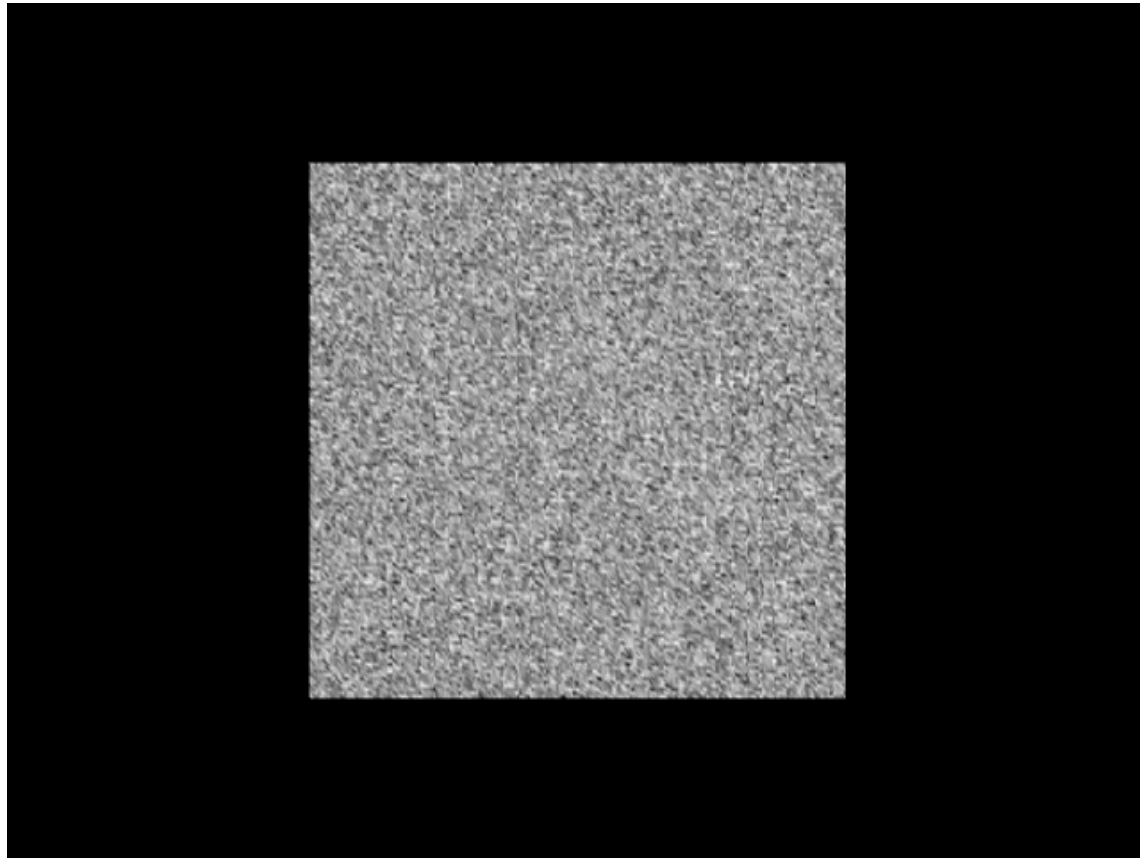


Neuronal tuning to object features in IT ensures a distinct population of activity to faces of different identities

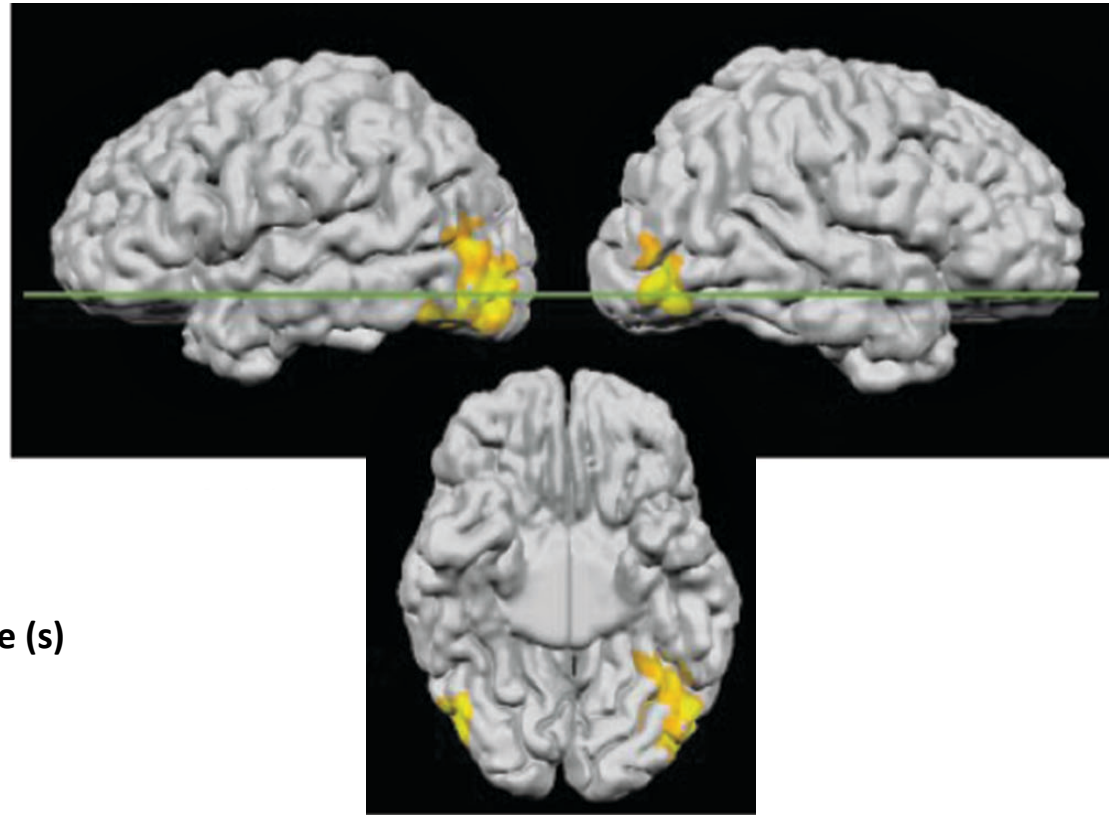
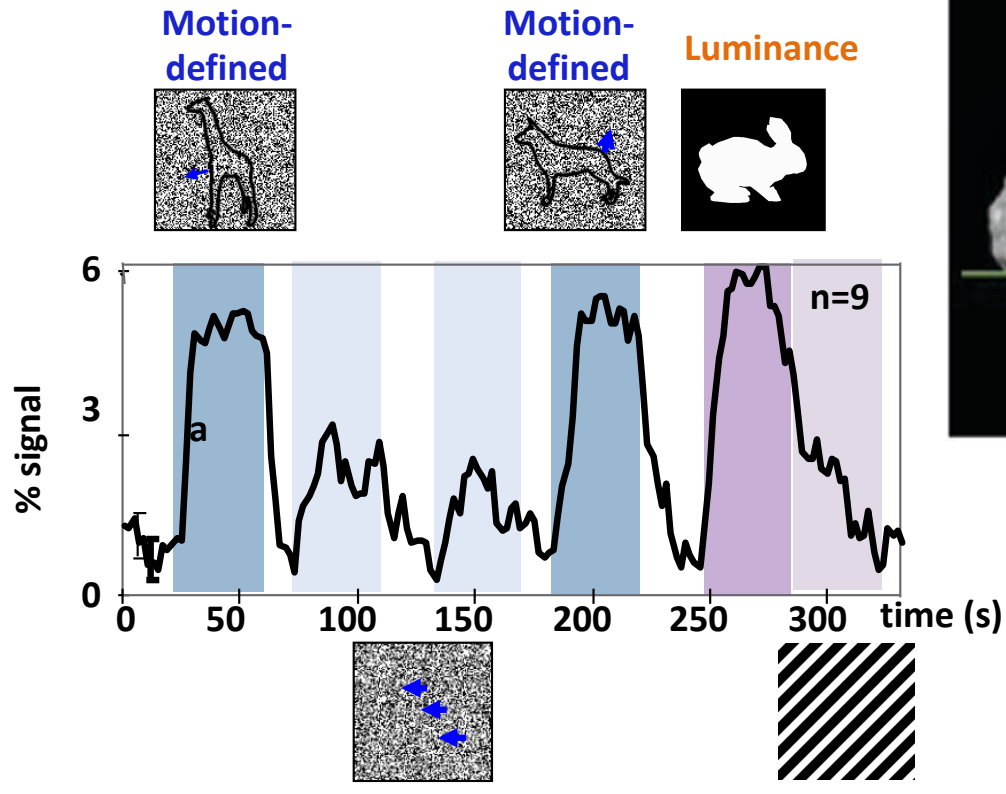


DiCarlo & Cox 2007 *TICS*

## Lateral object complex: extracting form



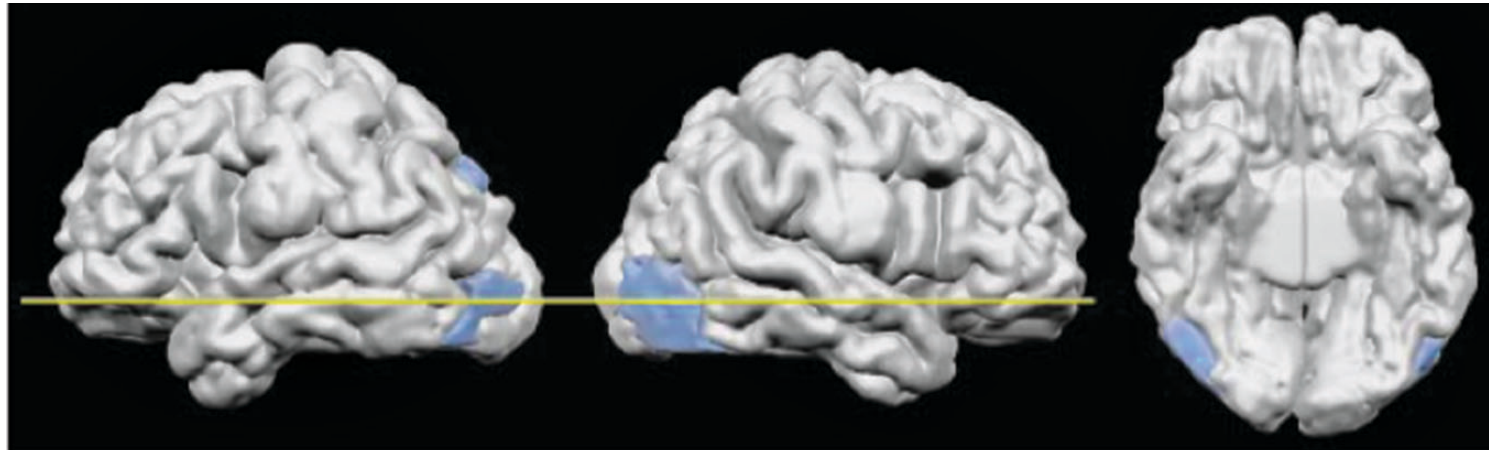
# Lateral object complex: extracting form



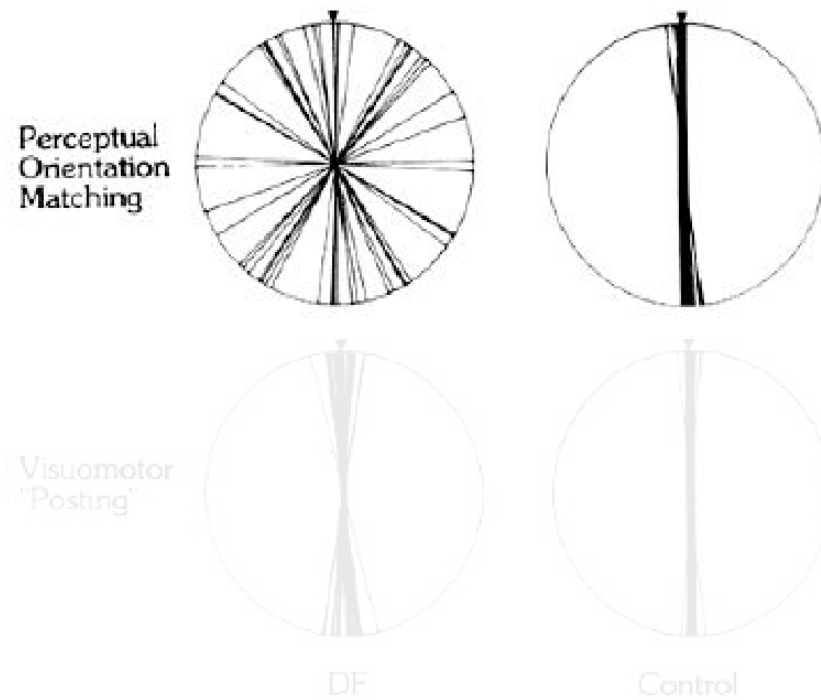
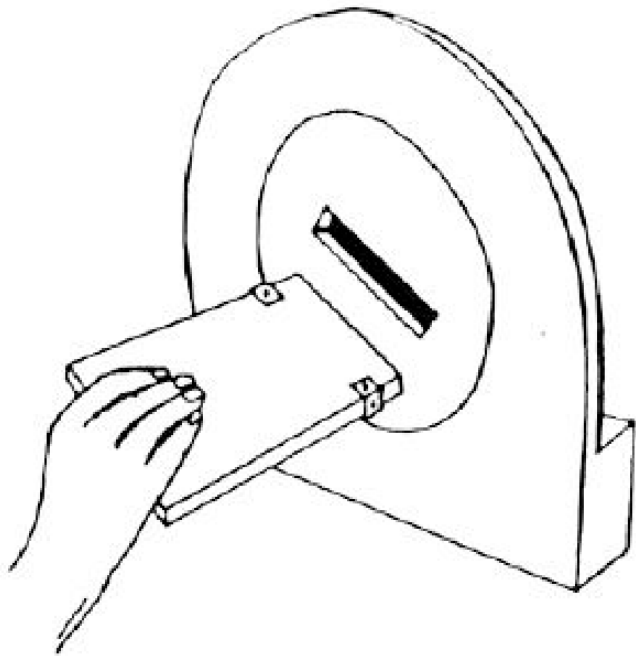
Grill-Spector et al. 1998; Mendola et al 1999; Kastner et al 1999; Kourtzi et al 2001



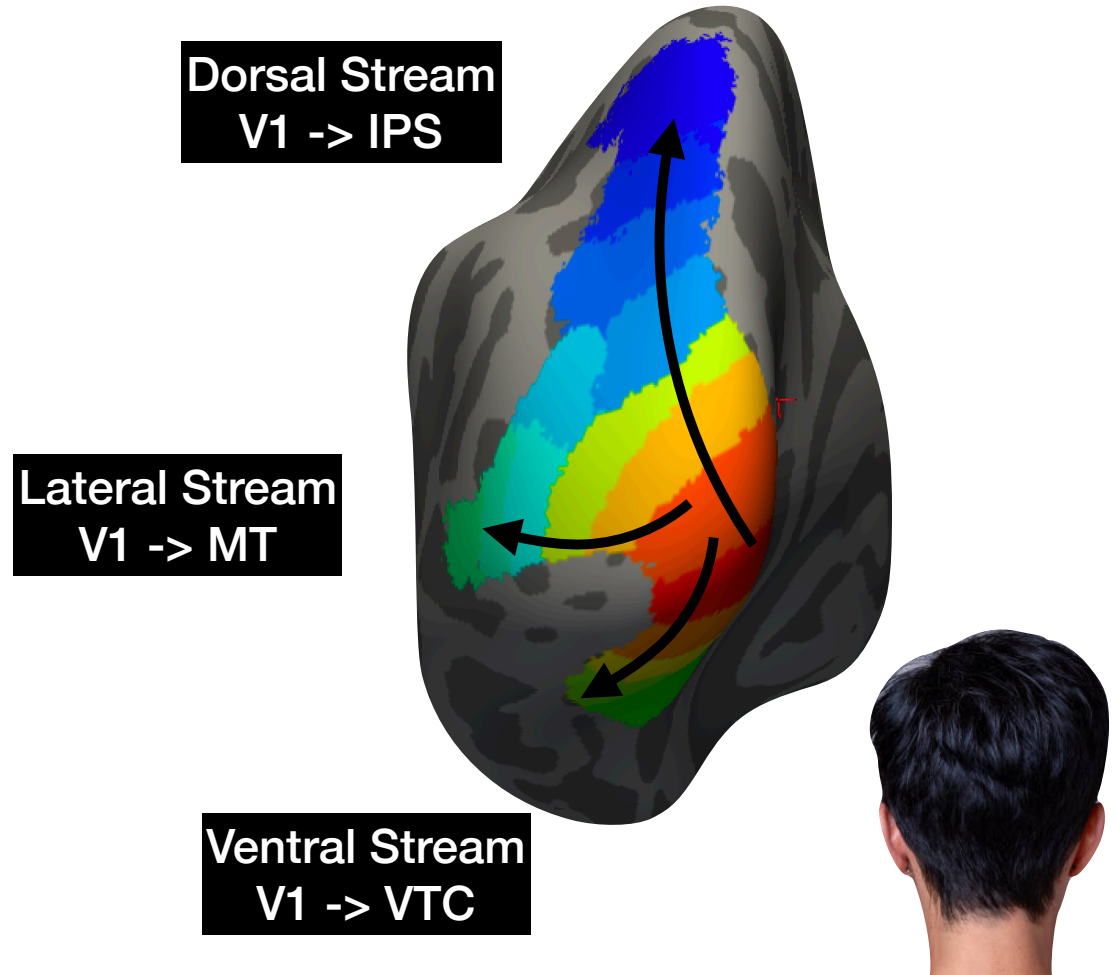
## Patient DF: a lesion resulting in bilateral LOC loss



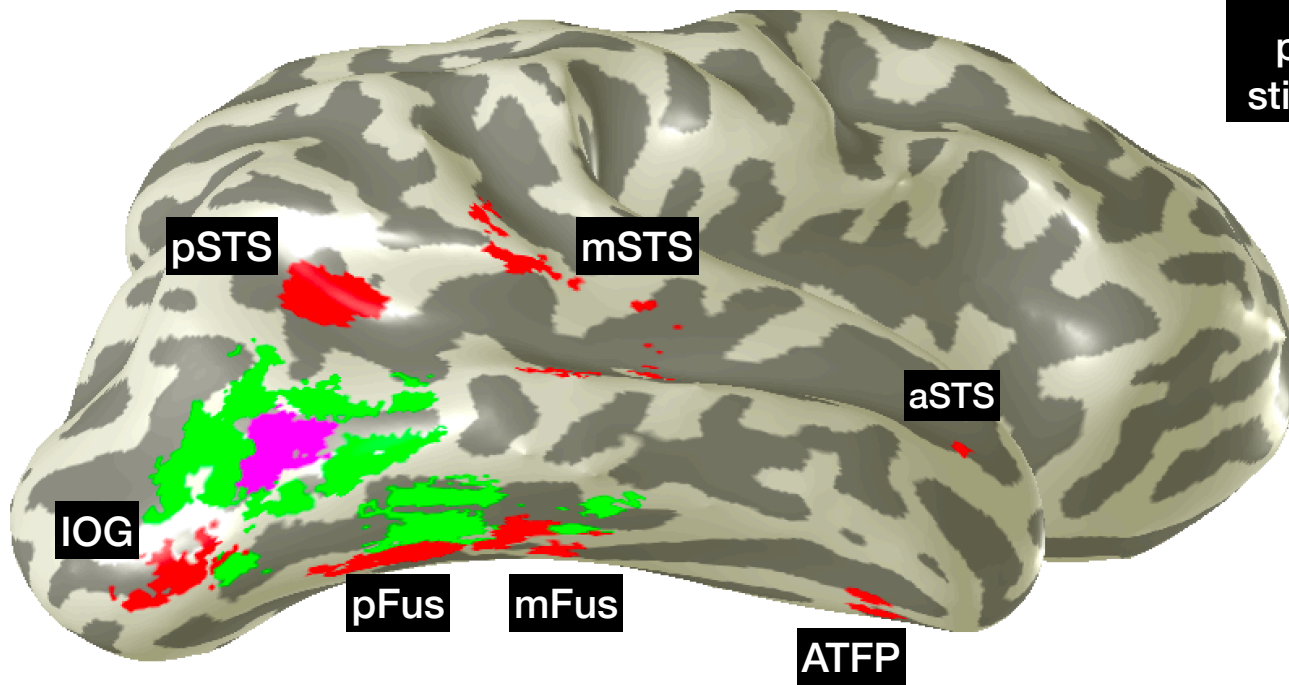
# Patient DF: a lesion resulting in bilateral LOC loss



# Patient DF's lesion led to the “two visual streams”

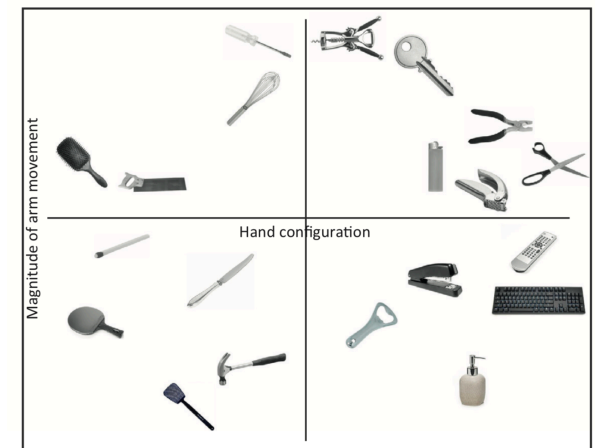


# Multiple object-recognition processing streams?



Lateral stream may be involved in processing the dynamic aspects of a stimulus (how it moves, its actions, etc).

pSTS is more activated by movies of dynamically moving faces compared to static faces, and together with multiple body/limb-selective ROIs, surrounds motion-selective region hMT+



Watson & Buxbaum 2014

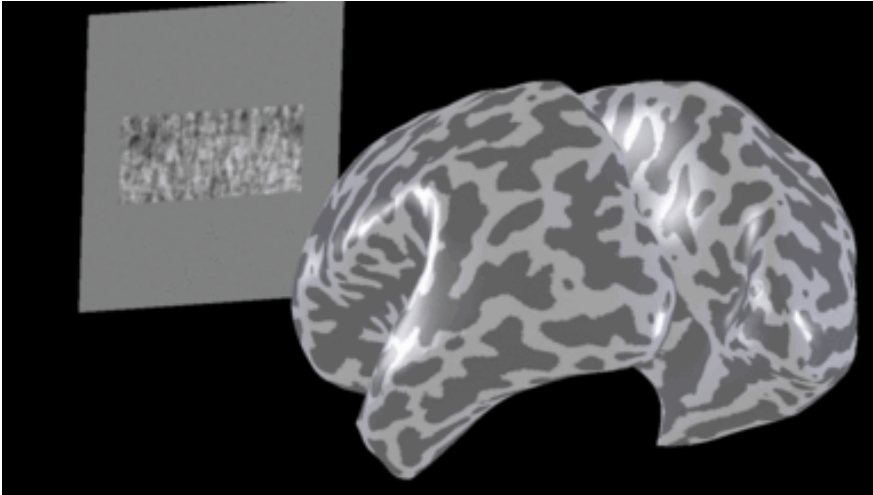
## Patient PS: damage to the IOG-face region



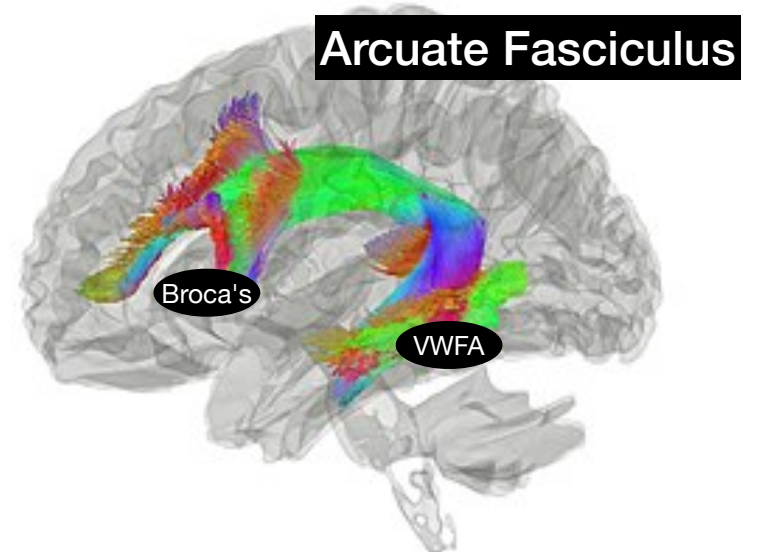
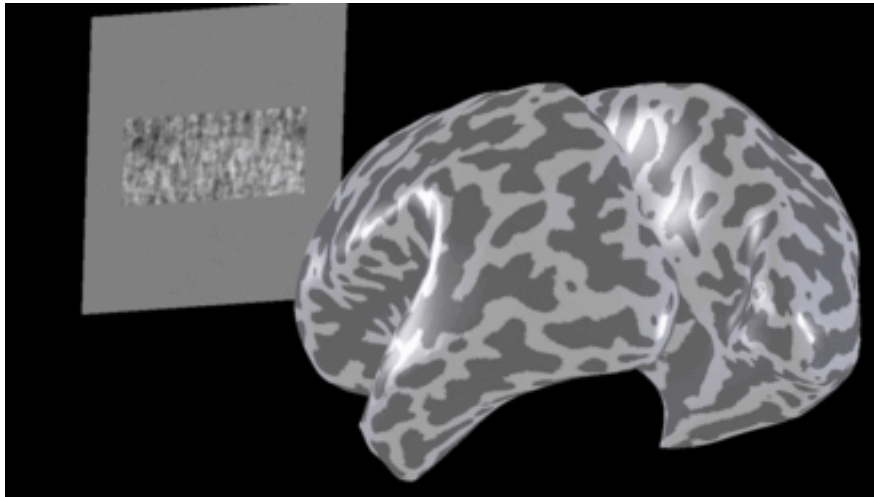
Bruno Rossion's Lab, see also Weiner et al. 2016



## Visual word-form area (VWFA): a module for reading text

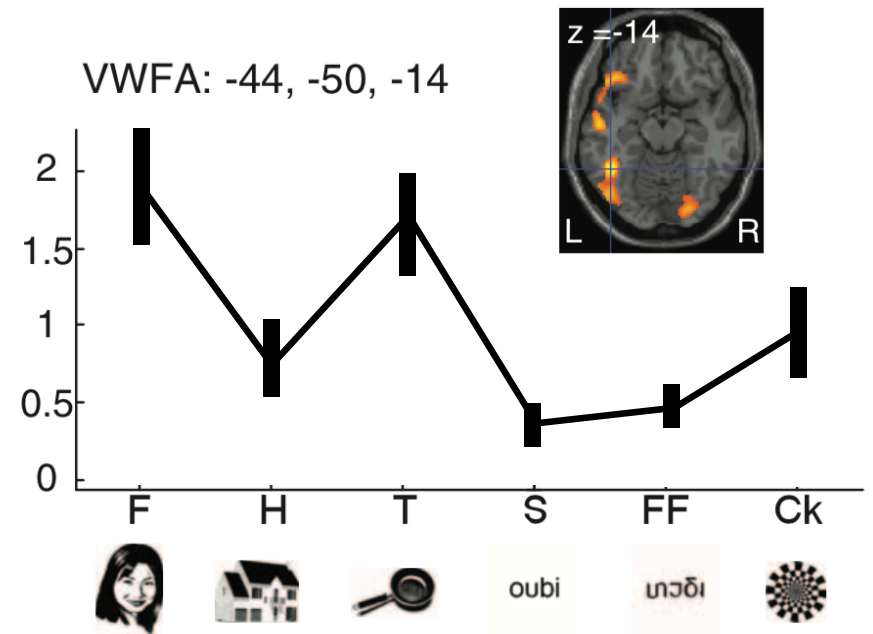
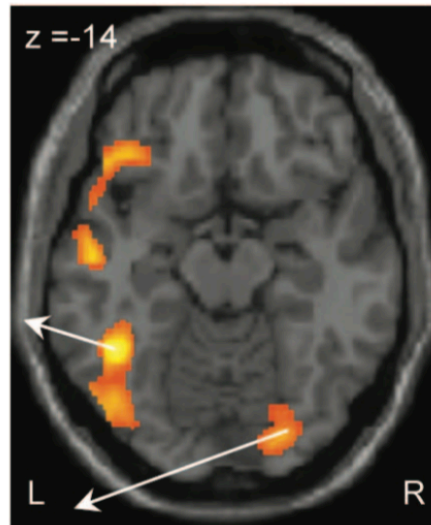
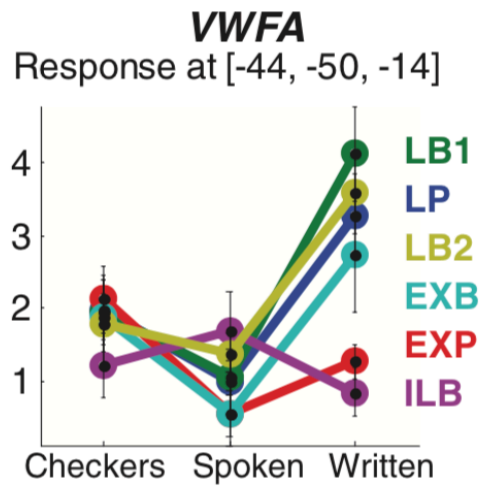


## Visual word-form area: a module for reading text

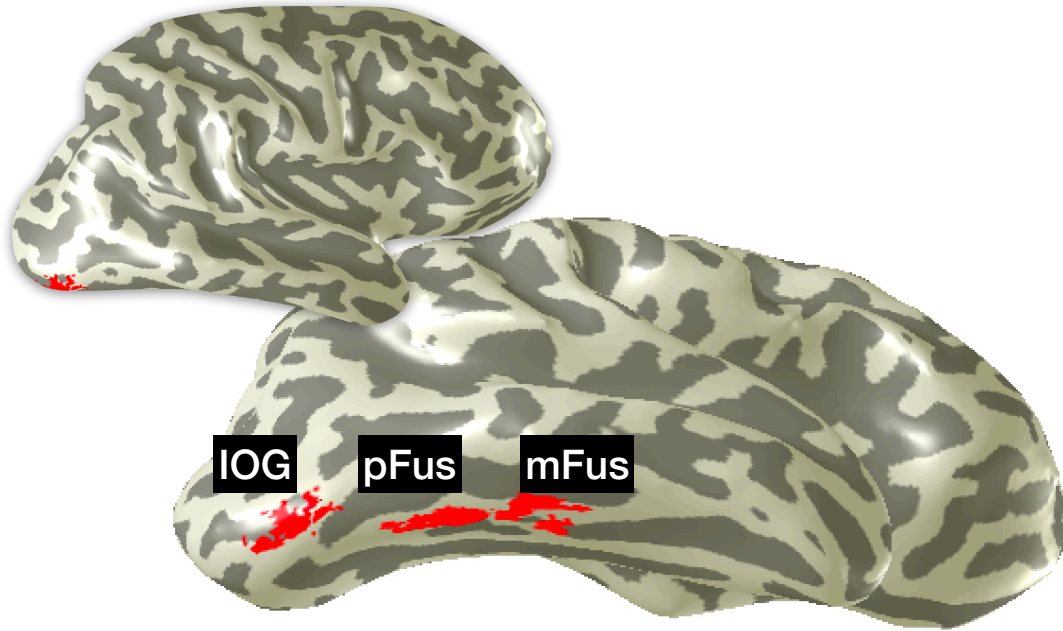


McCandliss et al. 2003; Wandell & Yeatman 2013; Wandell & Le 2017

# The VWFA is experience-dependent



# The "Fusiform face area" really a network, shows development



13.8



25.4

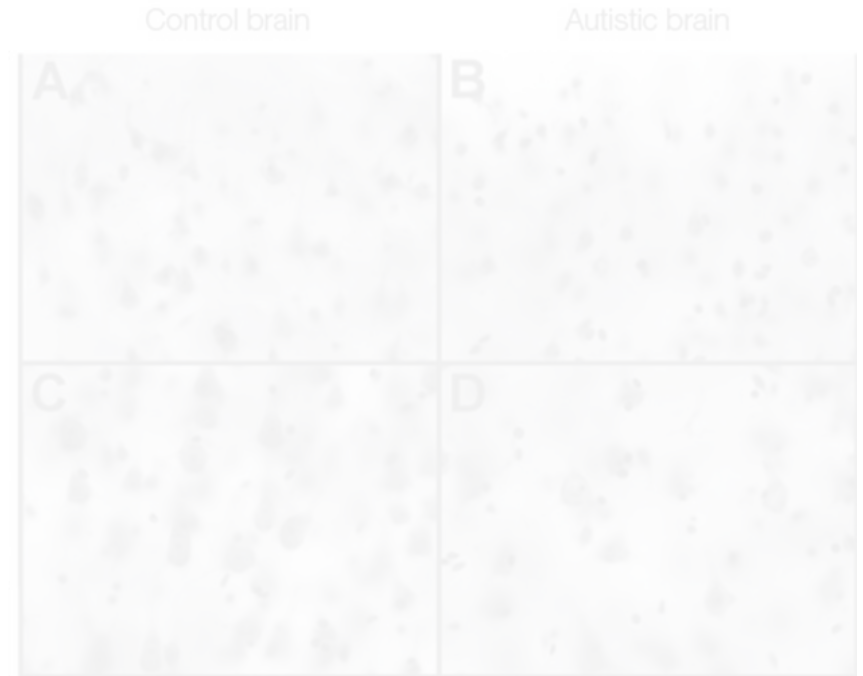
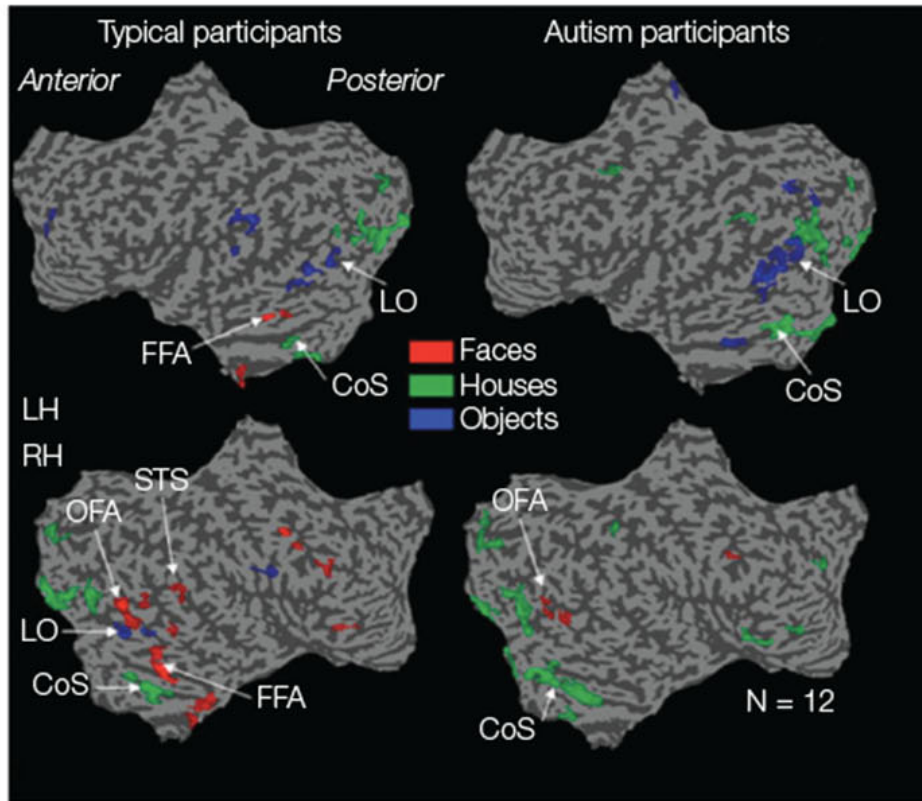


Kanwisher et al. 1997; Weiner & Grill-Spector 2012; Gauthier et al. 2000

Golarai et al. 2007, 2009



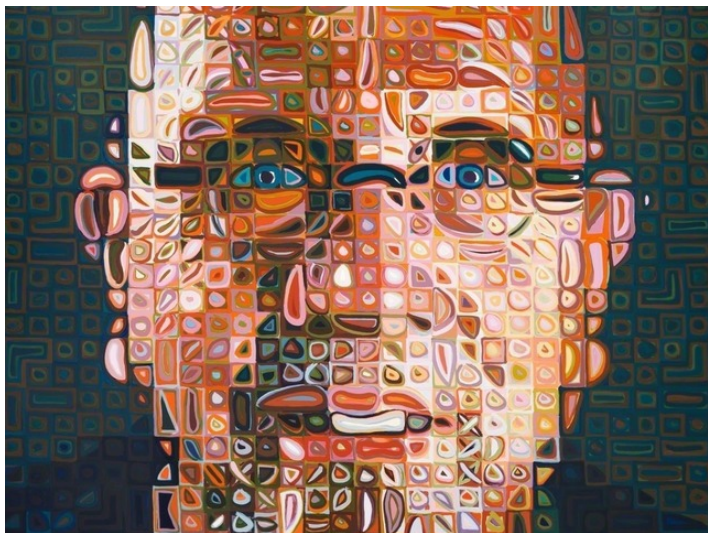
# Atypical development of high-level visual cortex



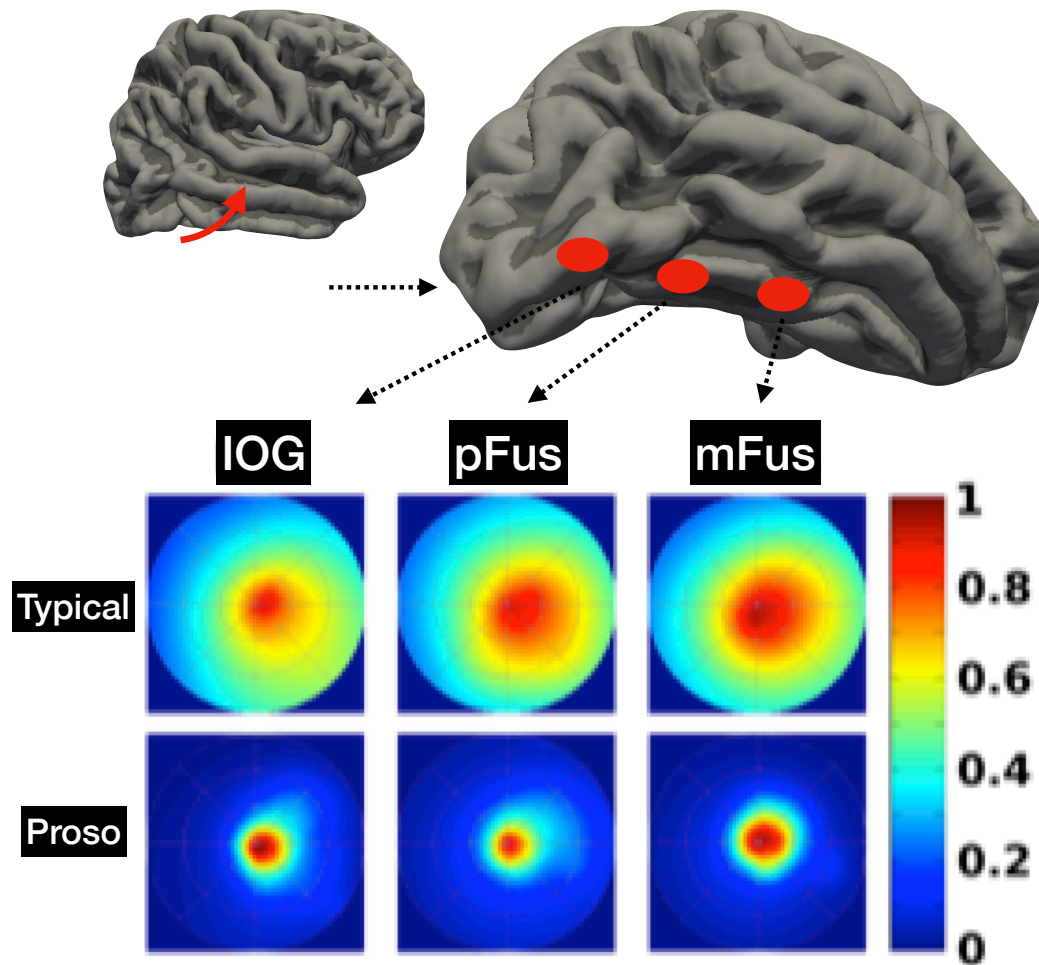
van Kooten et al., 2008

Corbett et al 2009; Humphreys et al., 2008

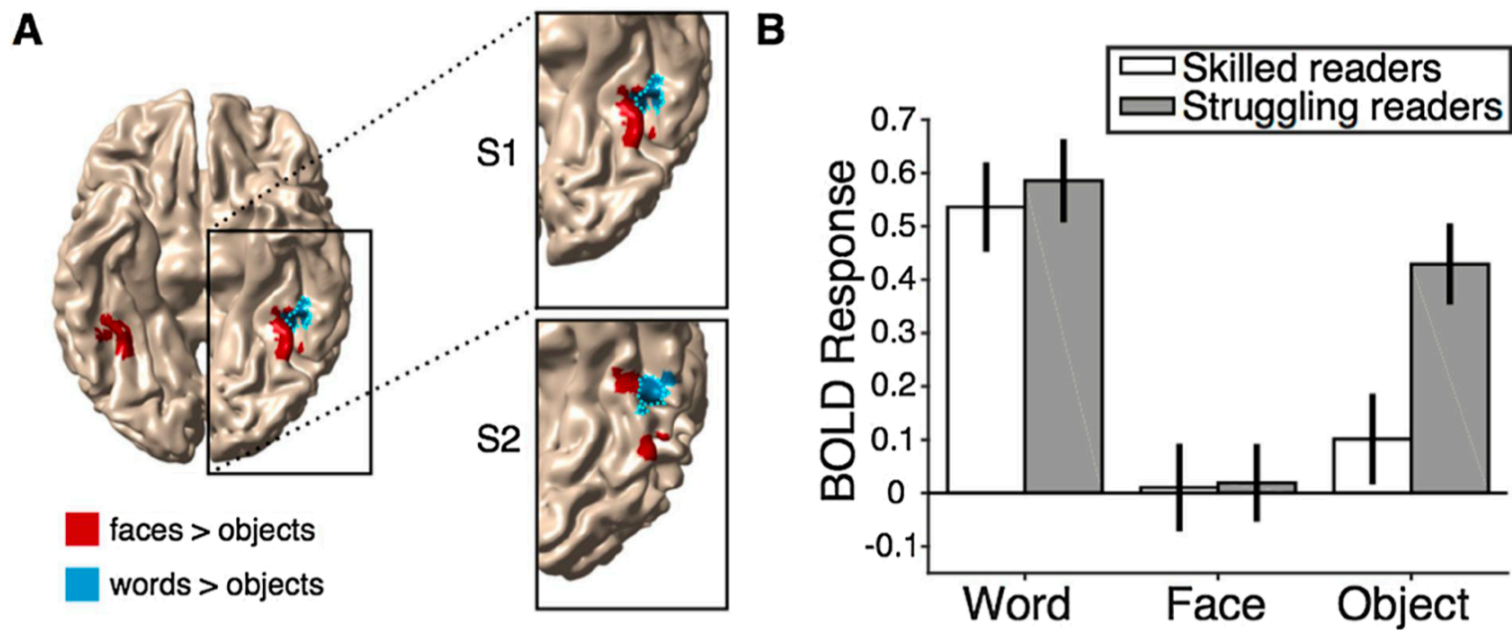
# Developmental prosopagnosia: face-blindness from a lack of spatial pooling?



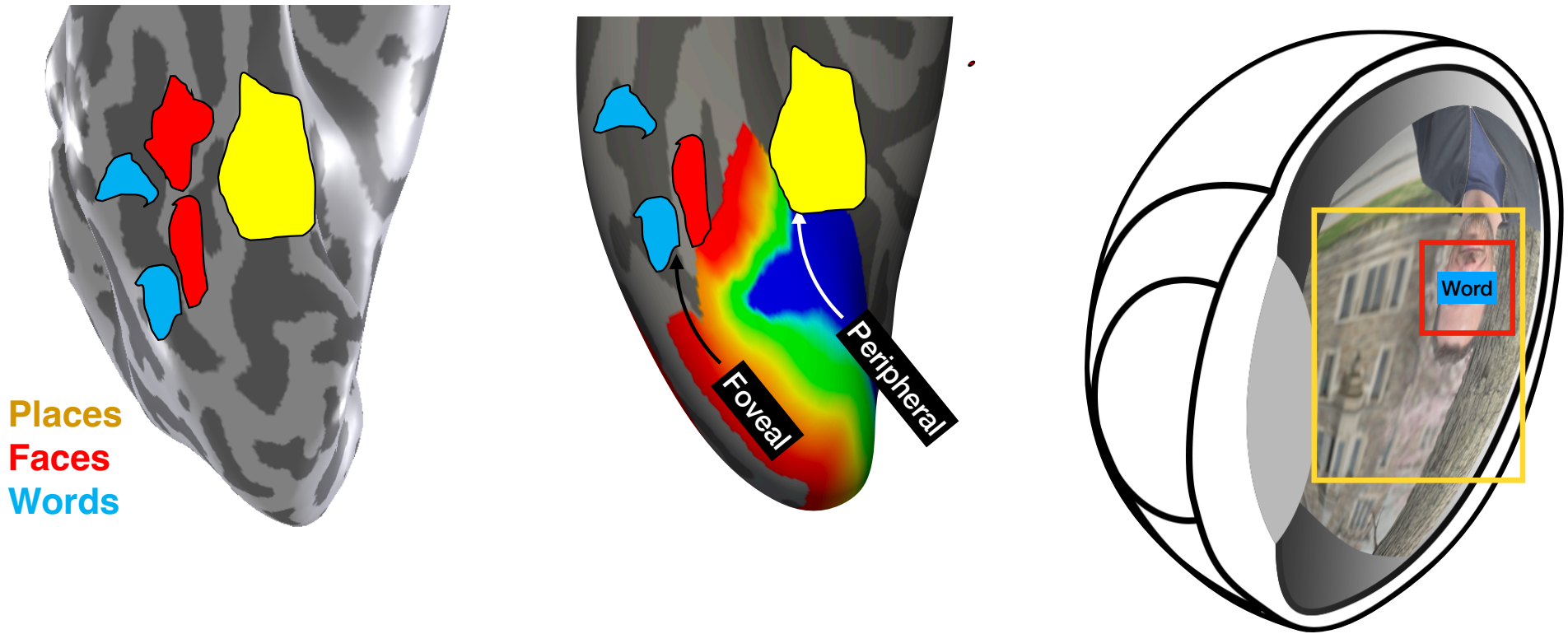
Chuck Close



# Some dyslexias may result from a high-level visual deficit

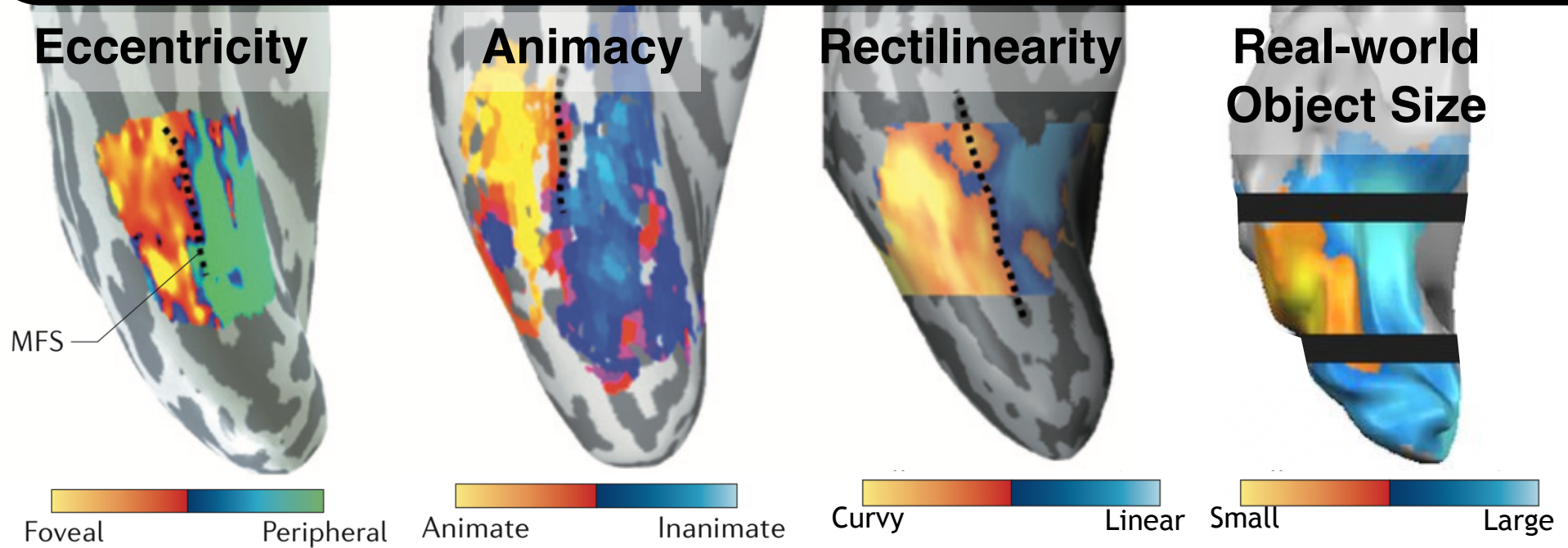


# Retinotopic connections combine with viewing biases to shape function

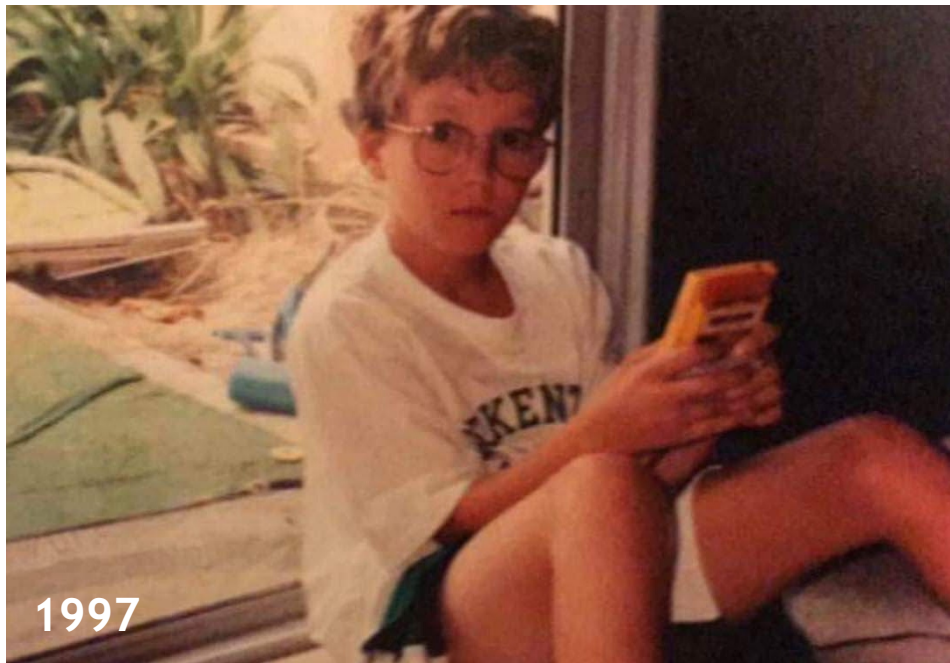




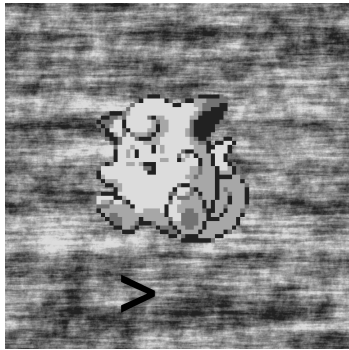
## Other potential organization schemes of high-level visual cortex



# What if you grew up learning a new visual category?



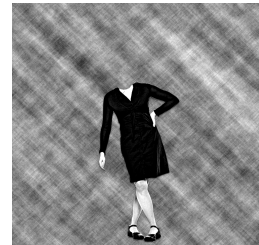
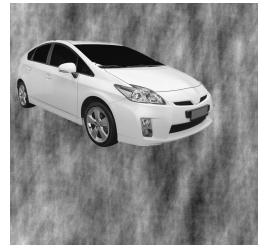
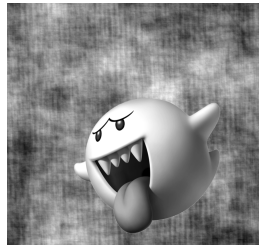
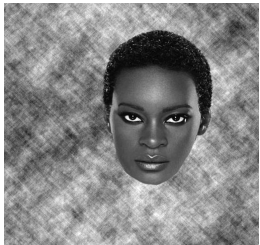
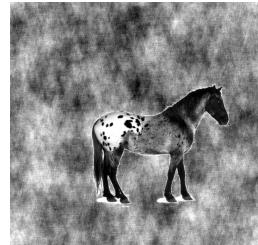
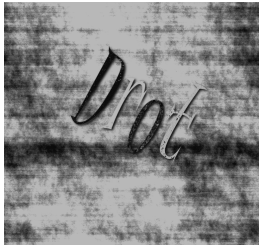
# Will extensive experience with Pokémon result in selectivity?



**11 Experts** (played 100s of hours between 5-8yo)

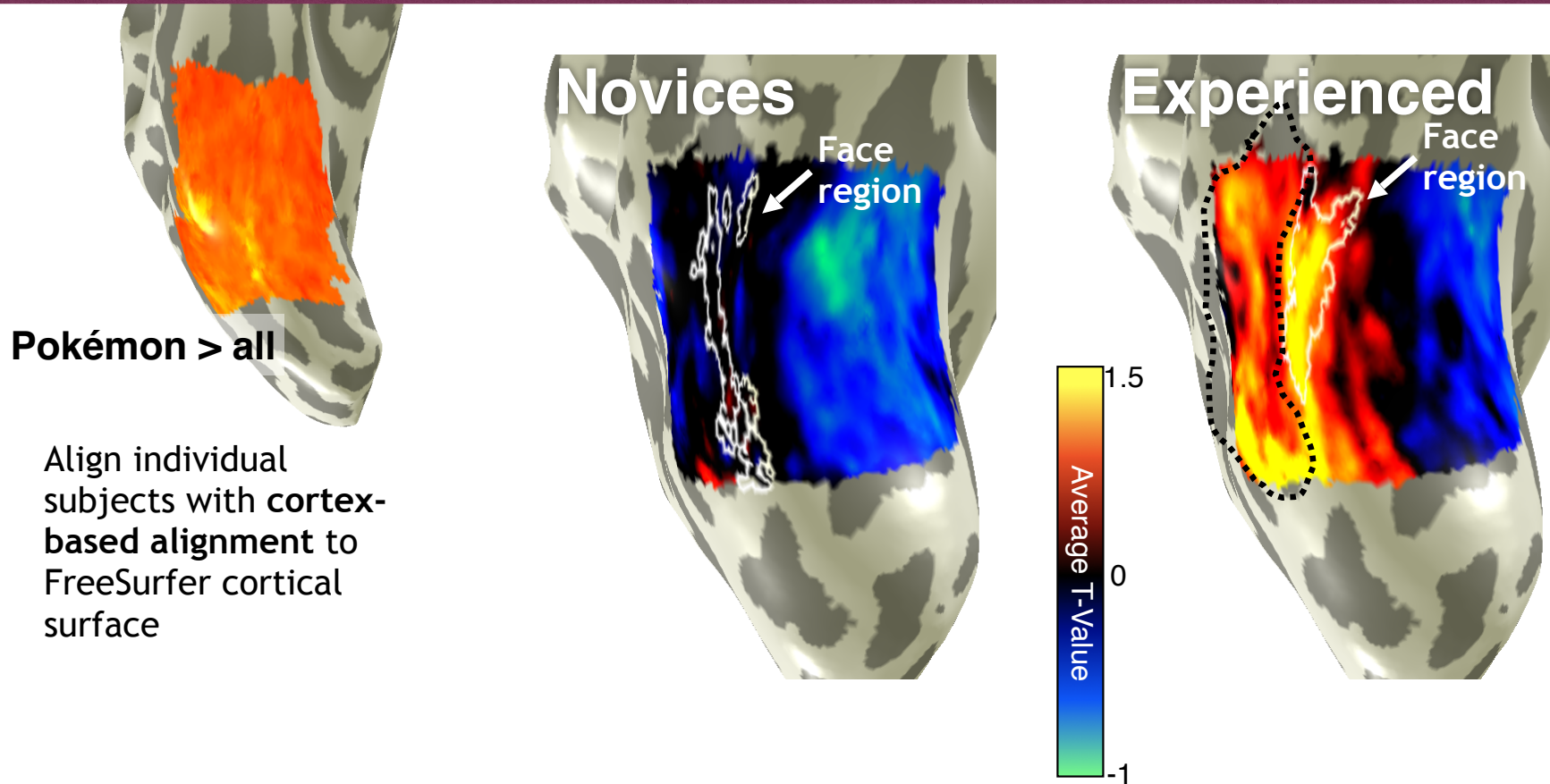
**11 Novices** (never played the game)

**6 runs of localizer** (fixation, performing oddball detection task, ~22 minutes of data)



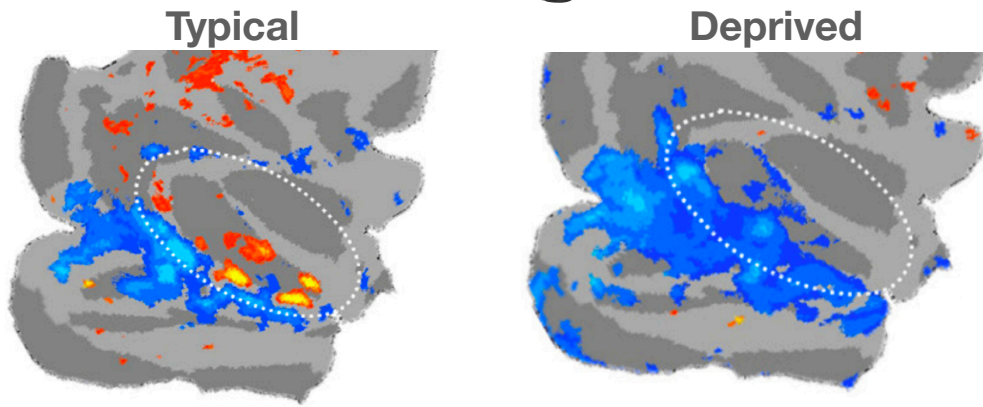
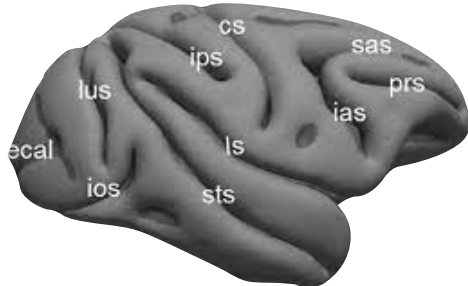


# Early Pokémon experience results in category-selective cortex





# "What you see is what you get", Livingstone & Arcaro



R

R

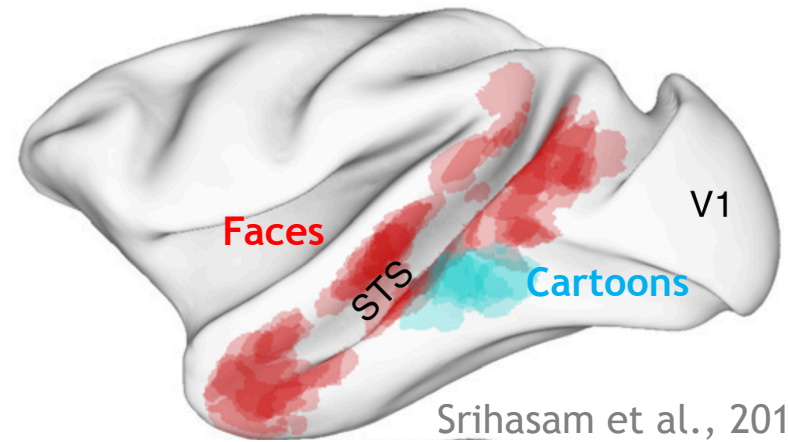
% signal  $\Delta$

4.0 0.1 4.0

Objects

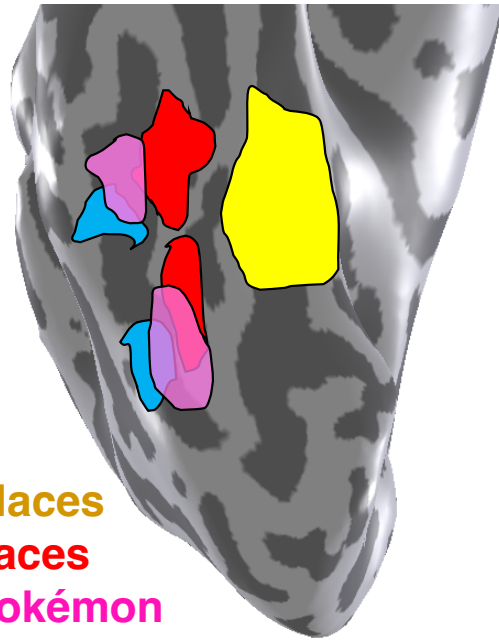
Faces

Arcaro et al., 2017

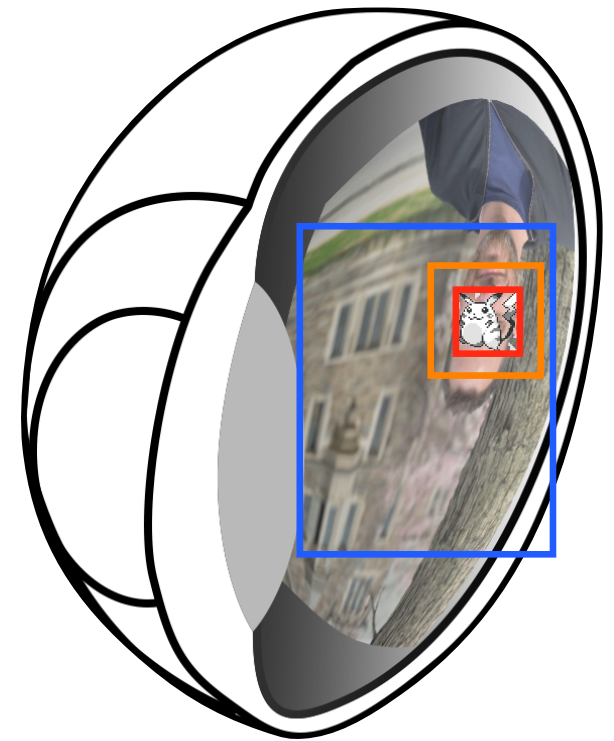
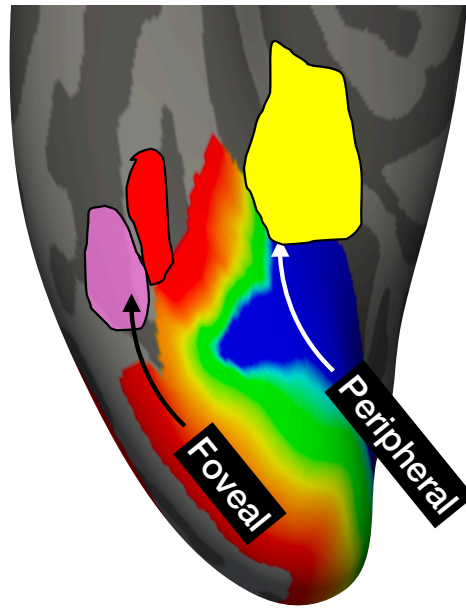


Srihasam et al., 2014

# Retinotopic connections combine with viewing biases to shape function

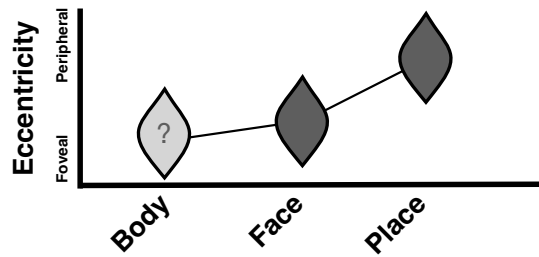
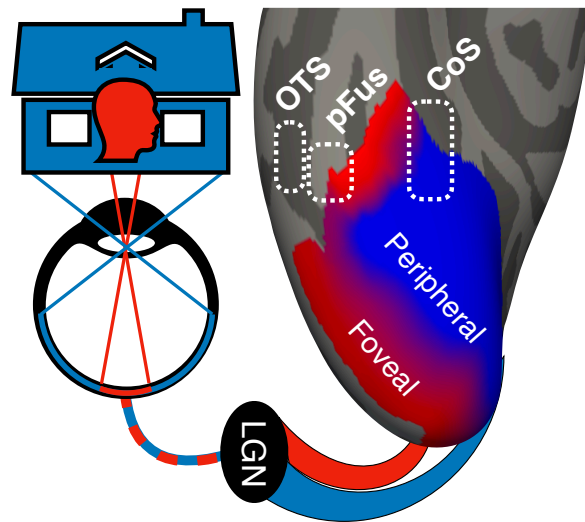


Places  
Faces  
Pokémon  
Words

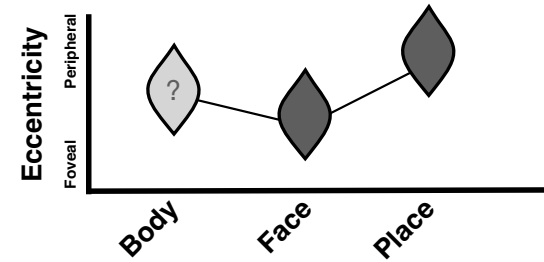
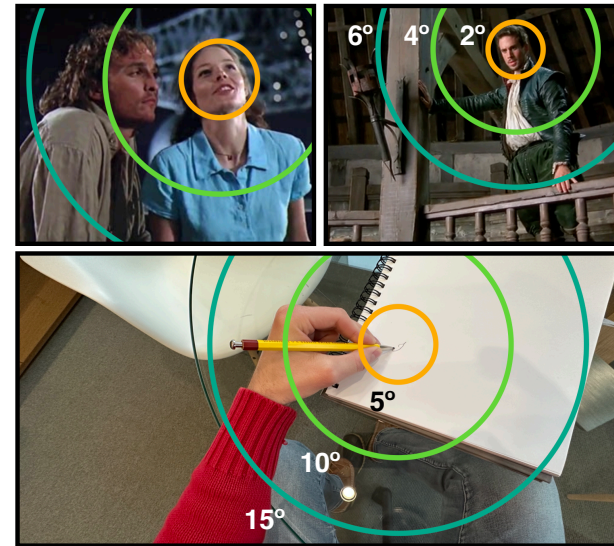


...but is that the whole story?

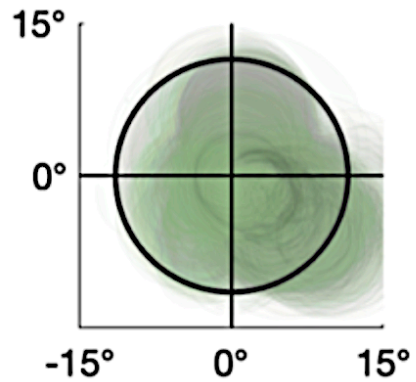
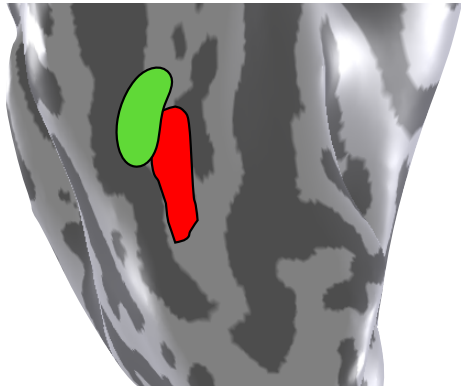
### Eccentricity Hypothesis



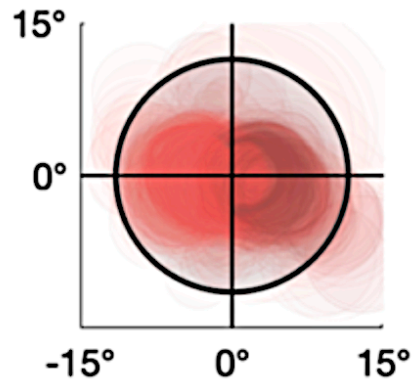
### Experiential Hypothesis



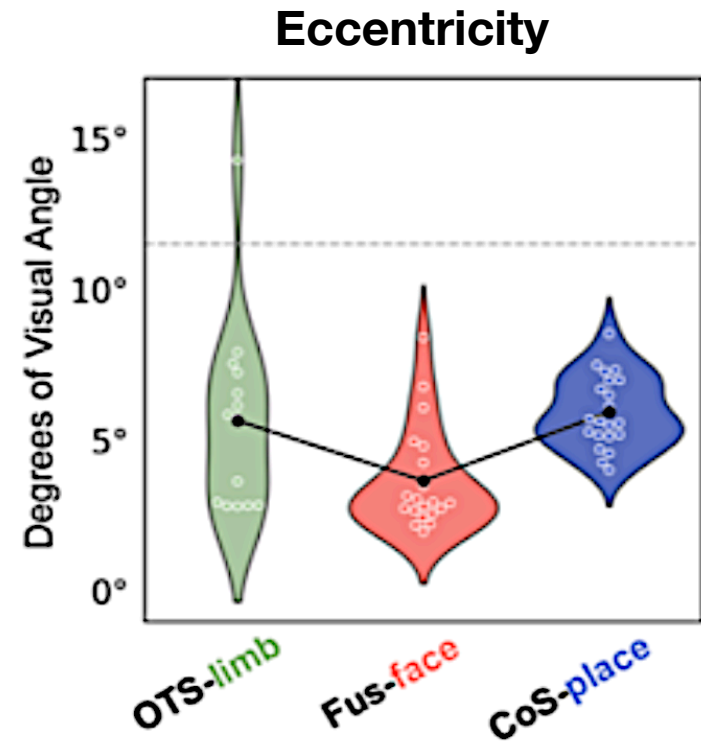
# Limb-selective cortex has peripheral pRFs that defy the eccentricity hypothesis



OTS-limbs



pFus-faces



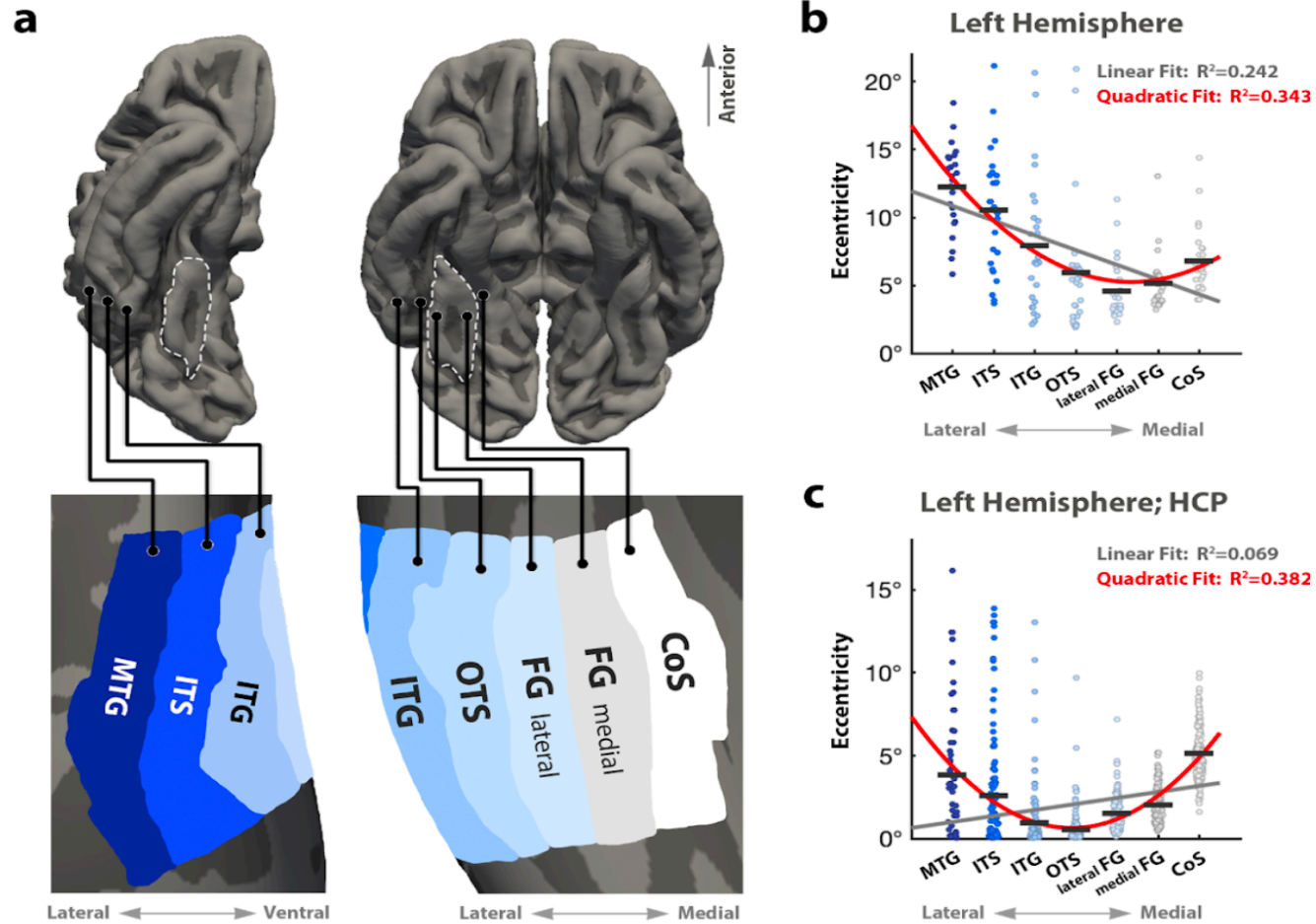
OTS-limb

Fus-face

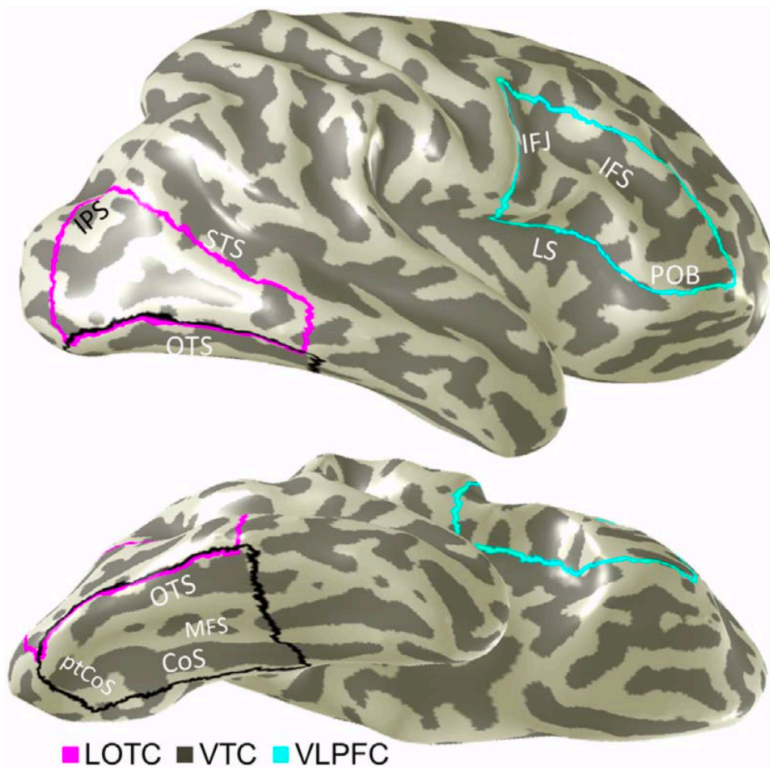
CoS-place



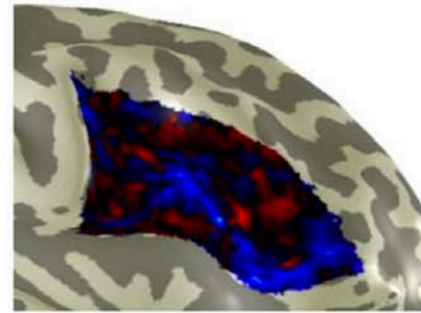
# Unless we expand the eccentricity hypothesis to include a second gradient



# Ventro-lateral prefrontal cortex: visual working memory?



VLPFC



OB



WM

VTC

