GEORGETOWN UNIVERSITY

Vision

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ICOS 7710

09/05/2024

How did I get here?

UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Urbana-Champaign, IL

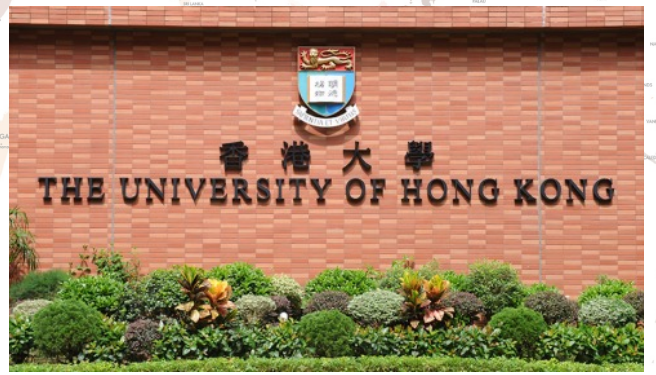
Pittsburgh, PA

Bethesda, MD

Washington, DC

Nanjing

Hong Kong



南京外国语学校 NFLS 1963 NANJING FOREIGN LANGUAGE SCHOOL

"cradle of diplomats"

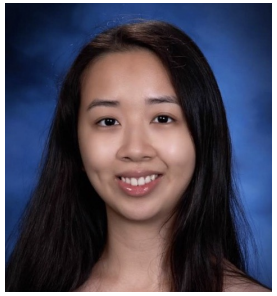
Trainee Map

Elena Younhye Ock
University of Colorado Boulder

Adam Dickter
Forbes Hospital

Jason Fu
New York Medical College

Lanie Bachmann
Columbia University



Bing Li
Princeton University

Maeve Sargeant
East Carolina University

Tori Gobo
Baylor College of Medicine

Eye tracking:

- Hsiao & **Liu** (2012). *Journal of Vision.*
- Kronemer, Gobo, Japee, Merriam, Osborne, Bandettini, & **Liu** (SfN 2024; in prep)

Typical developing children (ABCD):

- Yang, **Liu**, & Wang (2022). *Hum Brain Mapp.*
- Yang, **Liu**, & Wang (2023). *J Child Psychol & Psychiatry.*

Psychophysics:

- **Liu** & Behrmann (2014). *Front Hum Neurosci.*
- **Liu** et al. (2014). *Visual Cognition.*
- Ventura, **Liu**, Cruz, & Pereira (2022). *Mem Cognit.*
- Cavanaugh, **Liu**, Merriam, Duje, & Huxlin (VSS 2023; in prep).

Online crowdsourcing "big data":

- Bachmann, Japee, Merriam[#], & **Liu**[#] (2023). *Emotion.*

Computational methods:

- **Liu** et al. (2022). *Nature Communications.*
- Ventura*, **Liu*** et al. (2023). *Psychol. Aesthet.*

Visual behavior

Development

Lit Review/Journal club:

- **Liu** & Behrmann (2017). *Neuropsychologia*
- **Liu** (2024). *Nature Reviews Neuroscience*

Computation

Neuroimaging

Pediatric epilepsy/3T fMRI:

- **Liu** et al. (2018). *Cell Reports.*
- **Liu***, Freud* et al. (2019). *J Neuroscience.*
- Maallo, Freud, **Liu** et al. (2020). *Neuroimage.*
- Simmons, Granovetter, Robert, **Liu**, Patterson, & Behrmann (2024). *Neuropsychologia.*
- **Liu***, Granovetter* et al. (in prep).

7T (layer) fMRI:

- Chai, **Liu** et al., (2021). *Prog Neurobiol.*
- **Liu** et al. (2022). *Nature Communications.*
- Ock, Jones, **Liu**, & Merriam (in prep).
- **Liu**, Li, Bachmann, Cavanaugh, Fahrenthold, Melnick, Japee, Huxlin, & Merriam. (VSS 2023; in prep)

Meta-analysis:
Led by Kyungji Moon

Bibliometric analysis:
Led by Emma Gatewood

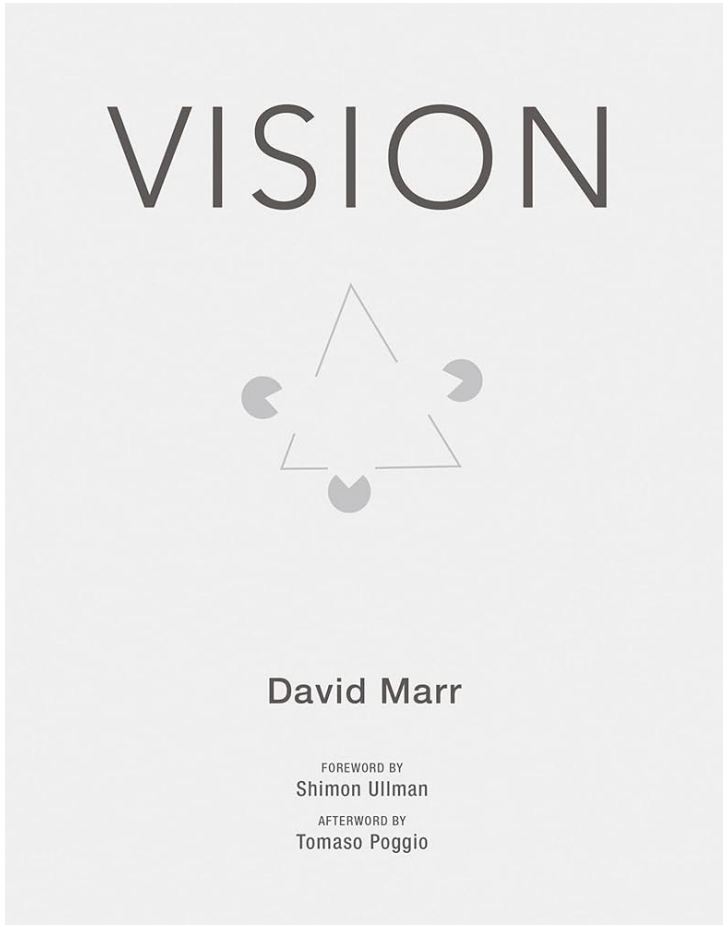
Transcranial brain stimulation:
the VIBRANT STUDY

Learning objectives

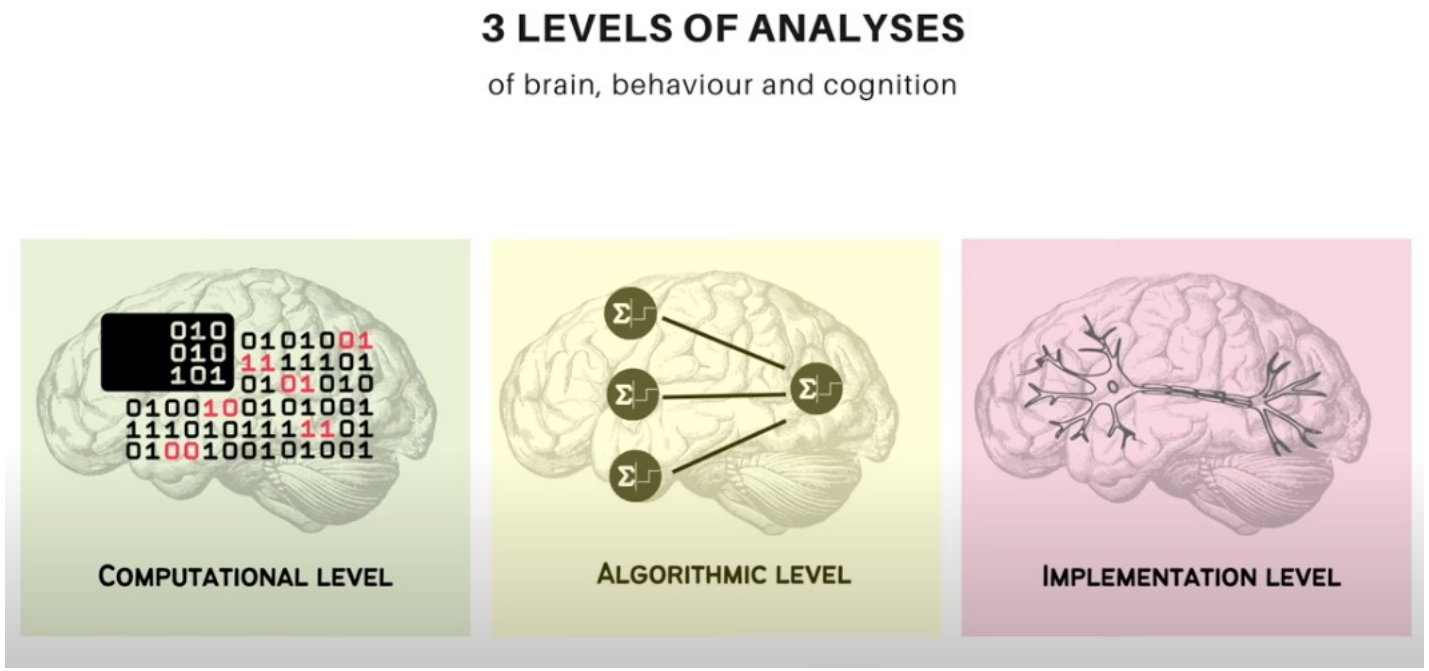
- Understand the roles of the early visual cortex and higher-order visual areas in visual processing
- Explain the functional distinctions between the ventral and dorsal visual pathways (Mishkin, Ungerleider, & Macko, 1983, *TINS*)
- Evaluate the evidence in the debate on the development of category selectivity in the ventral pathway (Arcaro & Livingstone, 2021, *NRN*)

Learning objectives

- Understand the roles of the early visual cortex and higher-order visual areas in visual processing



David Marr (Vision, 1982, p. 27): "[...] trying to understand perception by studying only neurons is like trying to understand bird flight by studying only feathers: It just cannot be done."



"Vision is the process of discovering from images **what** is present in the world, and **where** it is."

-- David Marr (Vision, 1982, p. 3)

Visual field

Source: CVI Scotland

Visual field

Source: CVI Scotland

Visual field

Source: CVI Scotland

Left homonymous hemianopia

hemi = half
anopia = without vision

Hemianopia
=
without vision in one half

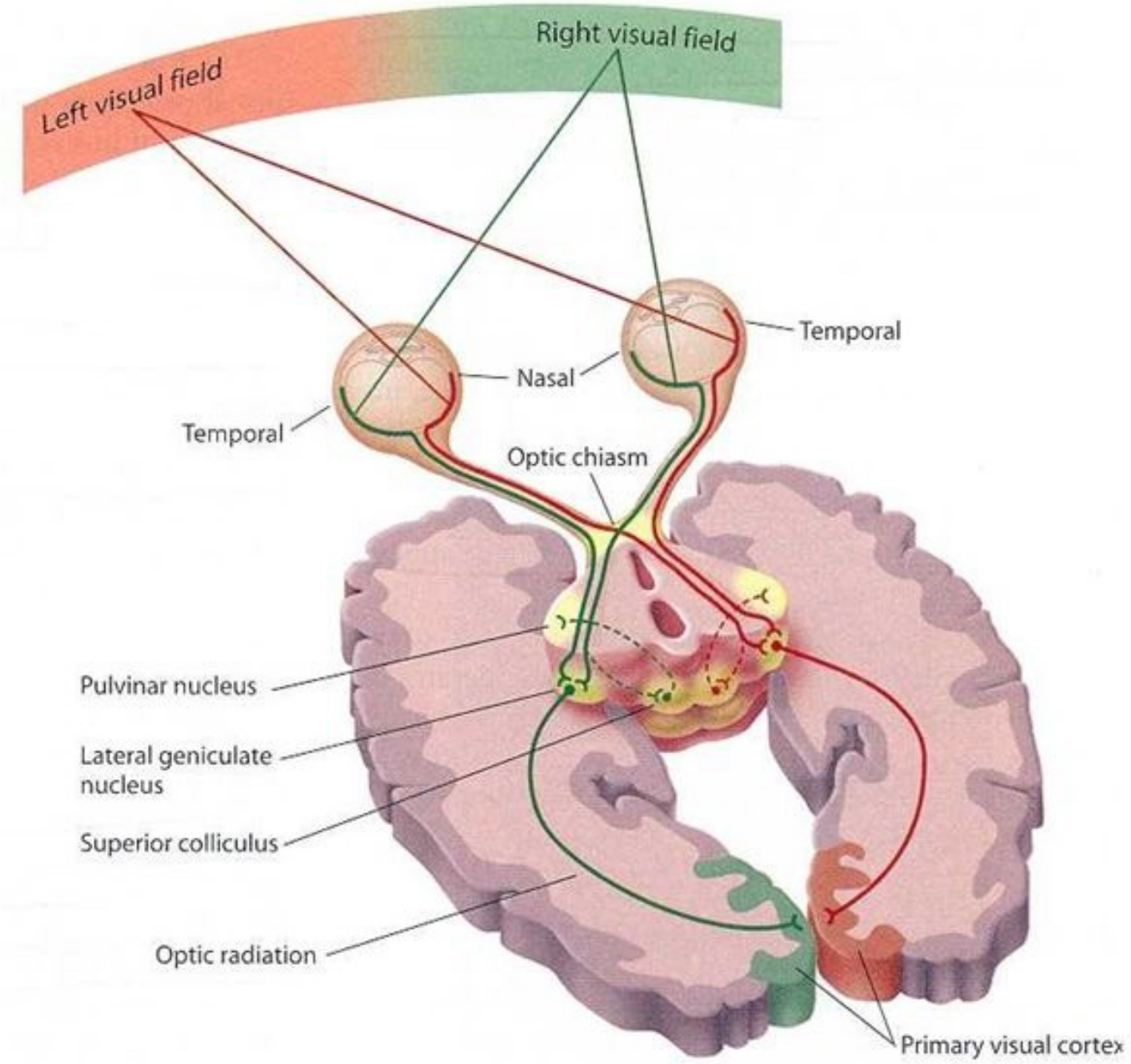
Pathway to brain

Geniculostriate pathway

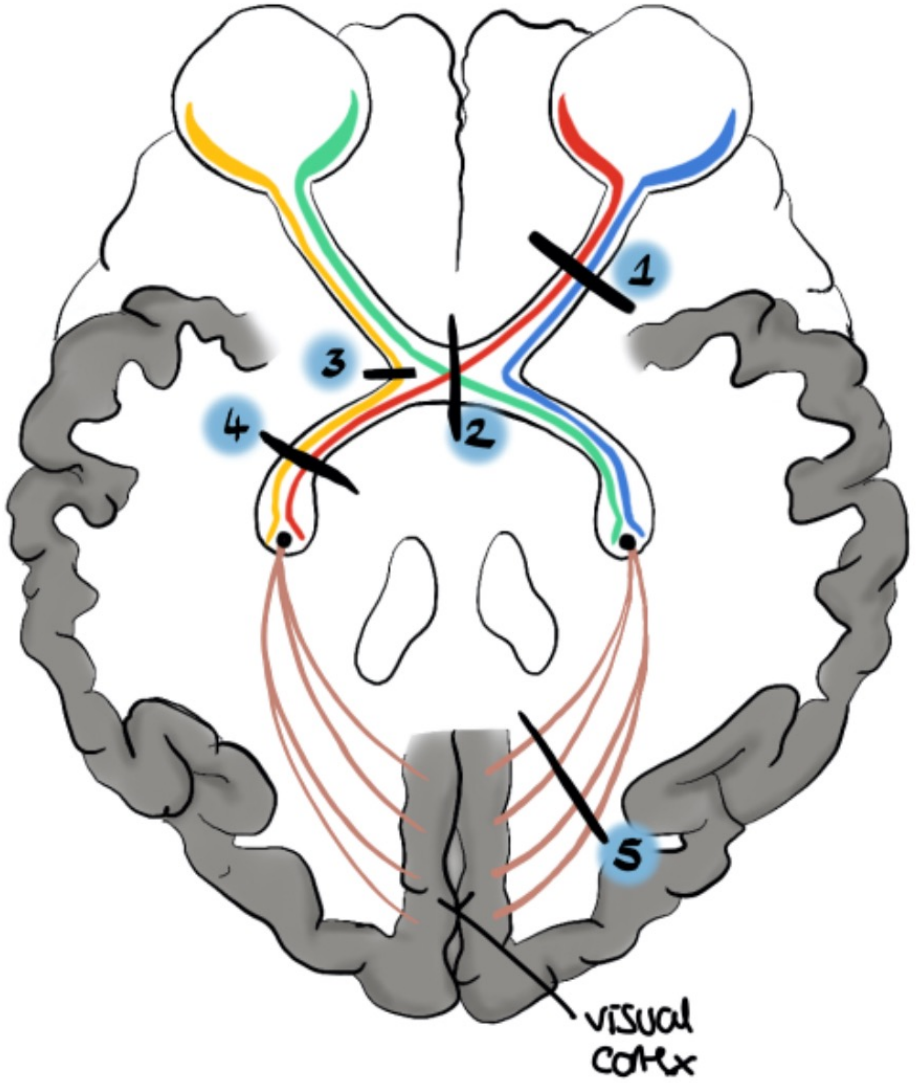
- Retina → LGN → V1
- about 90% of visual info

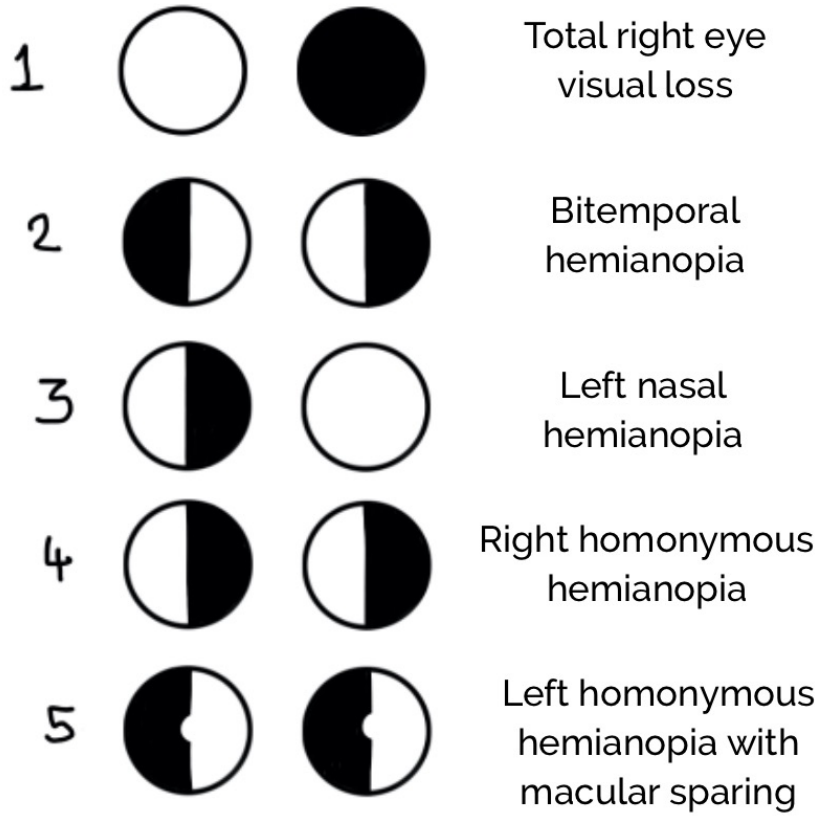
Tectopulvinar pathway

- Retina → SC → Pulvinar
- Dotted lines



Visual field defects

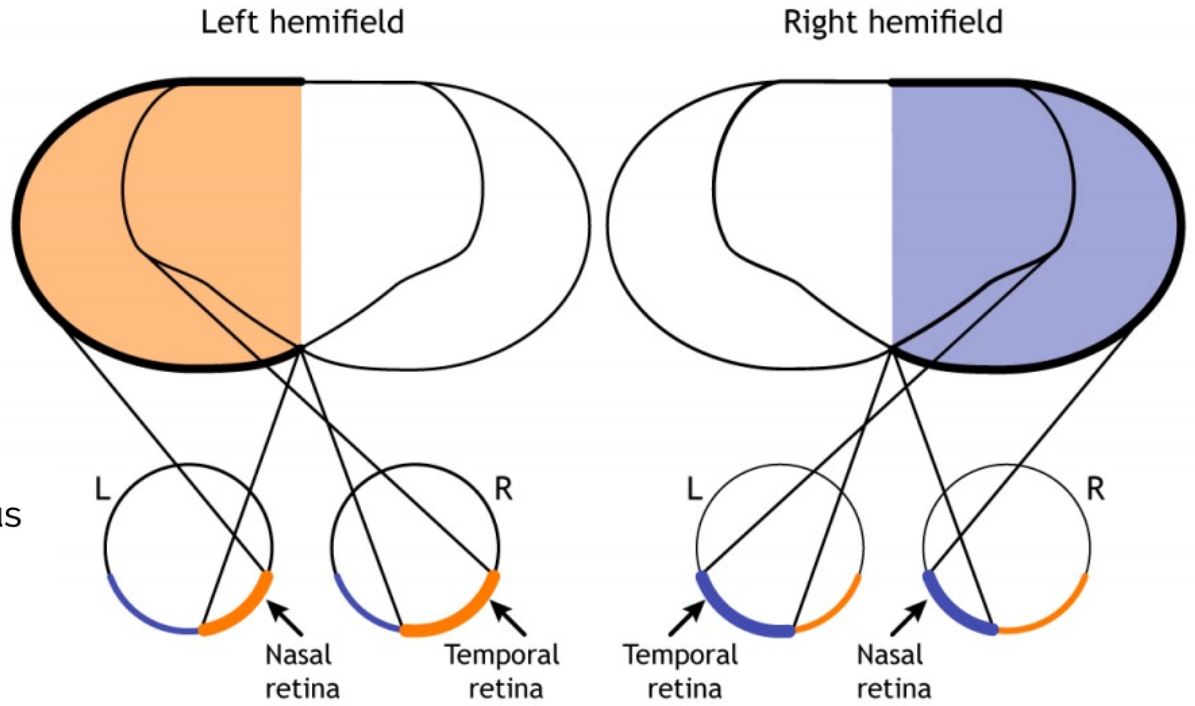




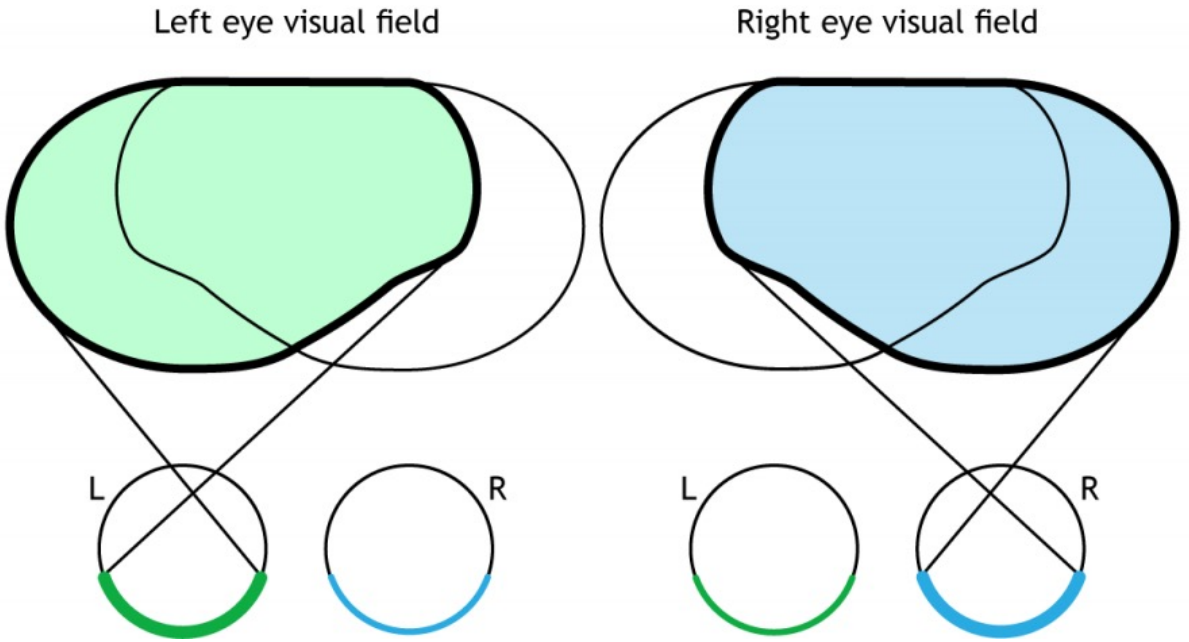
GEEKYMEDICS.COM

Cortical blindness

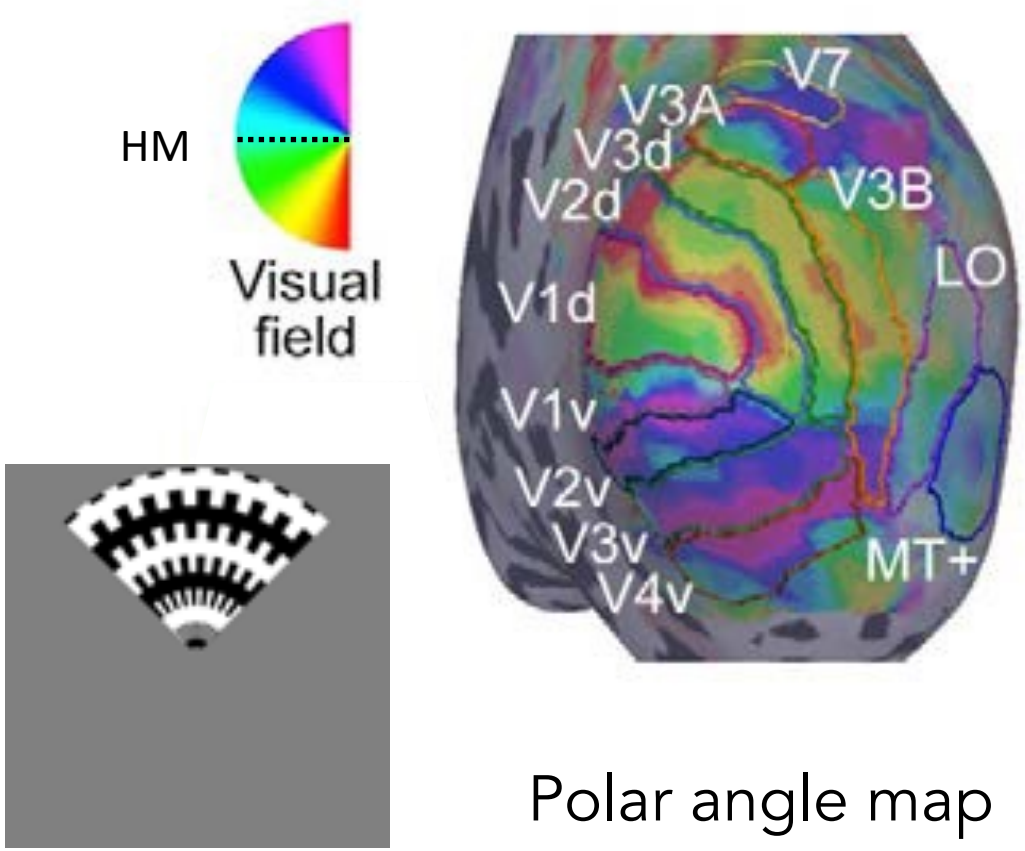
Right homonymous hemianopia



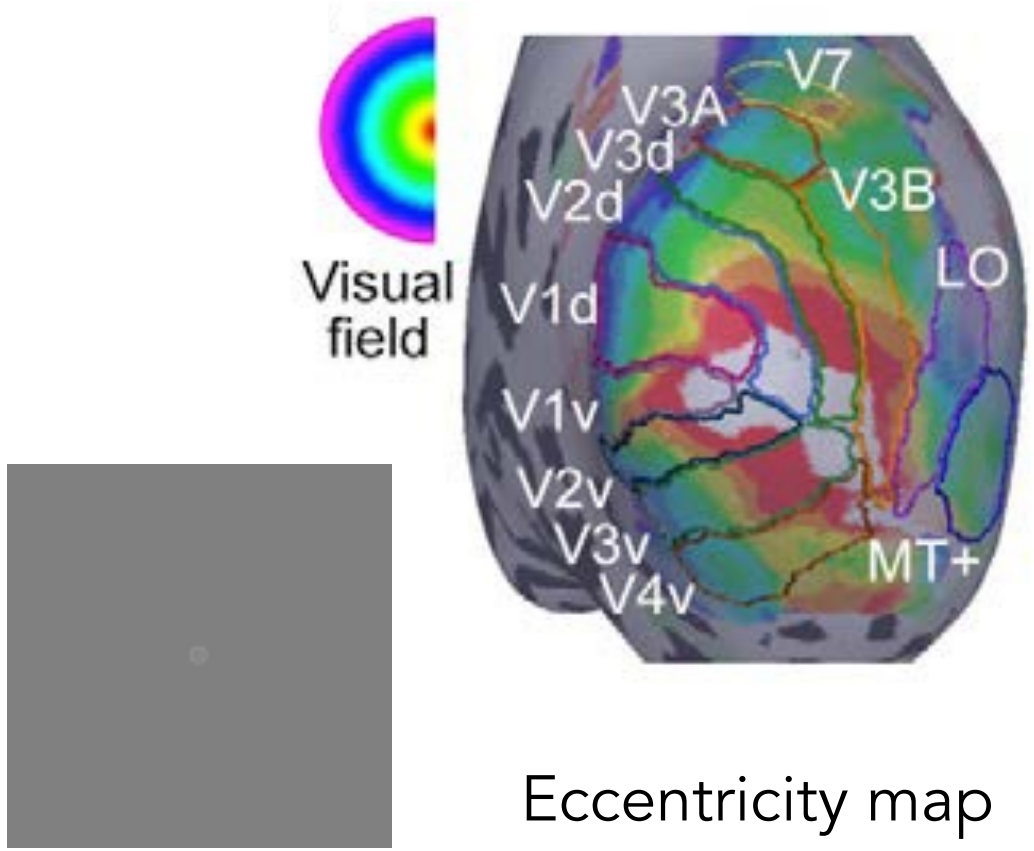
Total right eye visual loss



Retinotopic mapping in fMRI (EVC)



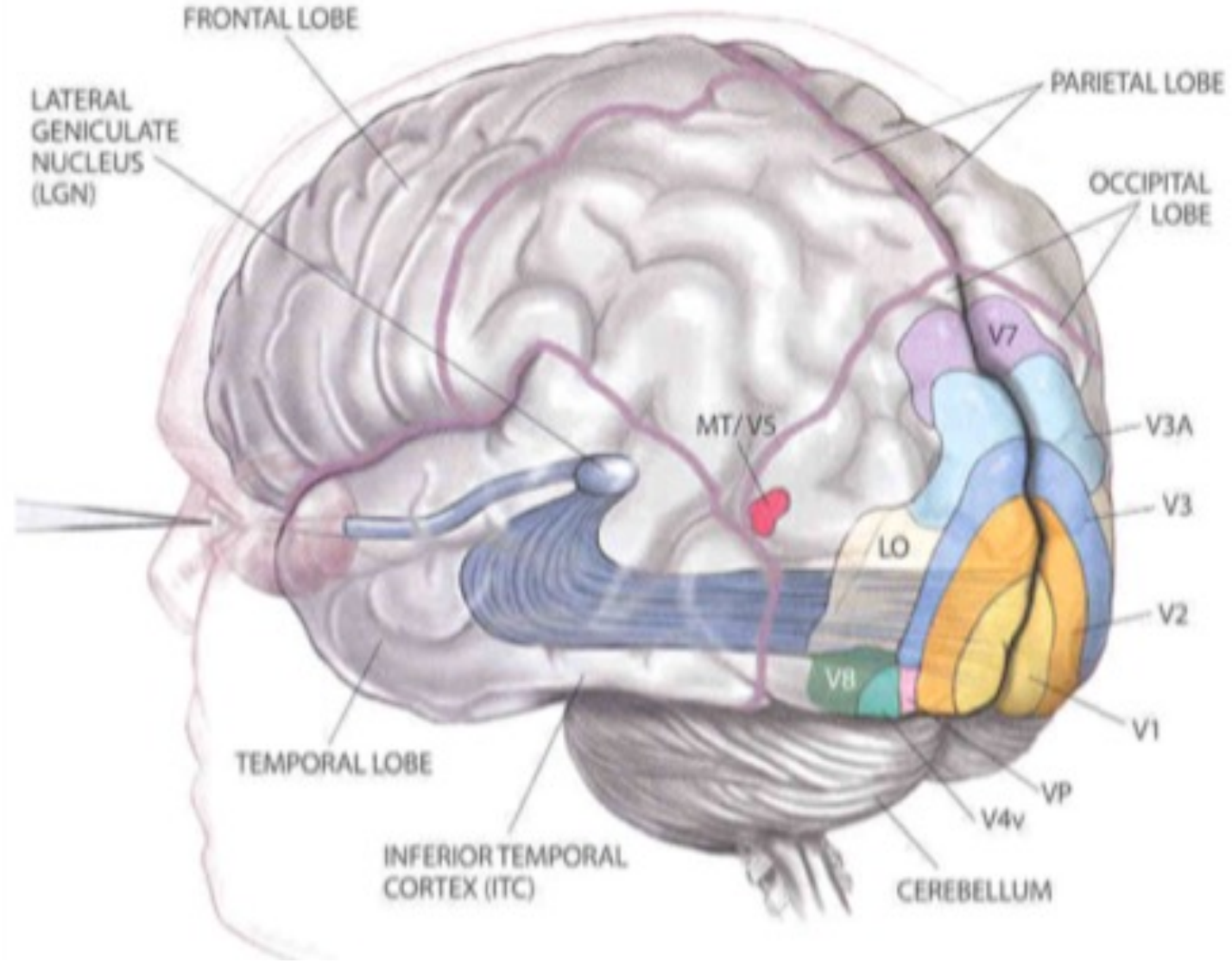
Polar angle map



Eccentricity map

Sereno, Dale, Reppas, Kwong, ... & Tootell. (1995). *Science*.

Early Visual Cortex



KEY TO FUNCTION

V1: Primary visual cortex; receives all visual input. Begins processing of color, motion and shape. Cells in this area have the smallest receptive fields.

V2, V3 and **VP:** Continue processing; cells of each area have progressively larger receptive fields.

V3A: Biased for perceiving motion.

V4v: Function unknown.

MT/V5: Detects motion.

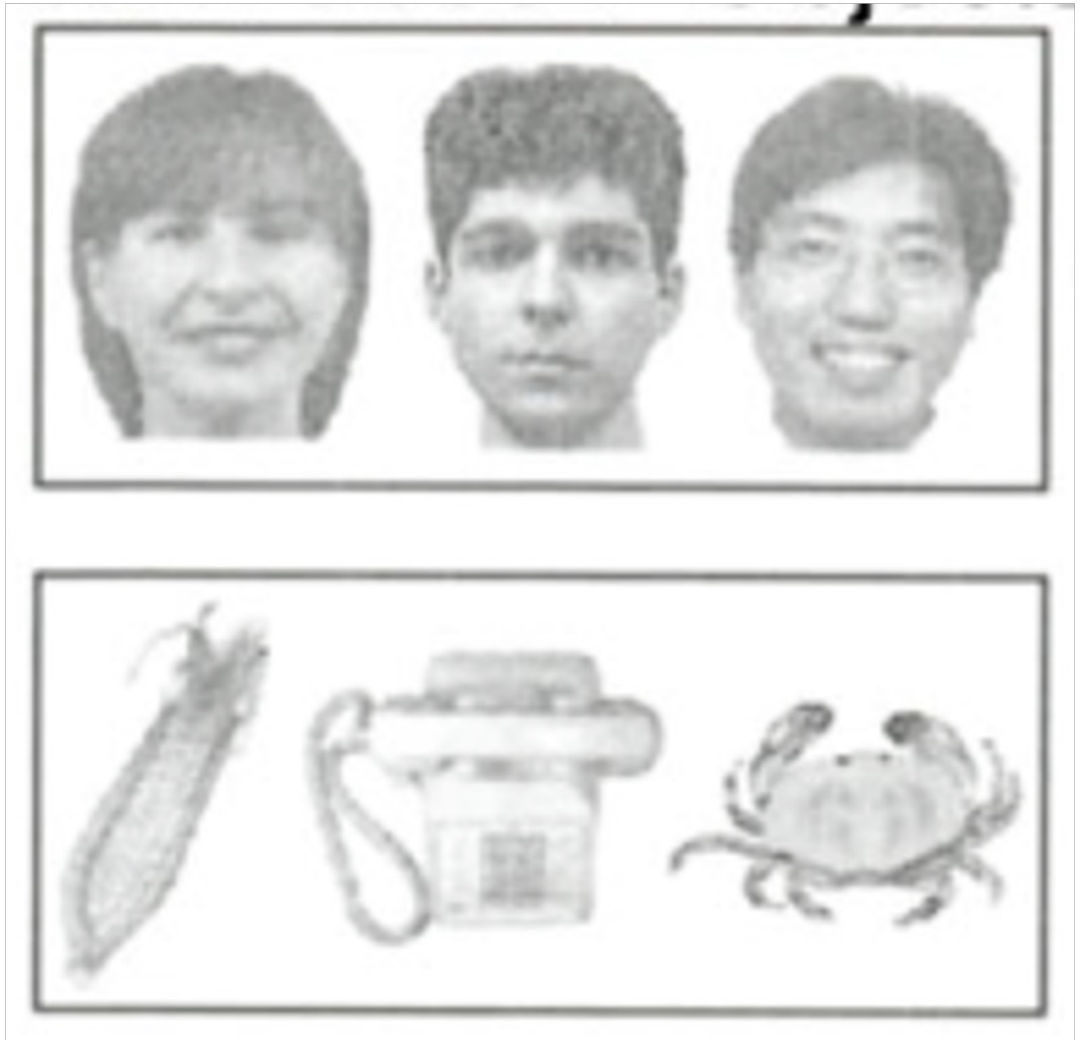
V7: Function unknown.

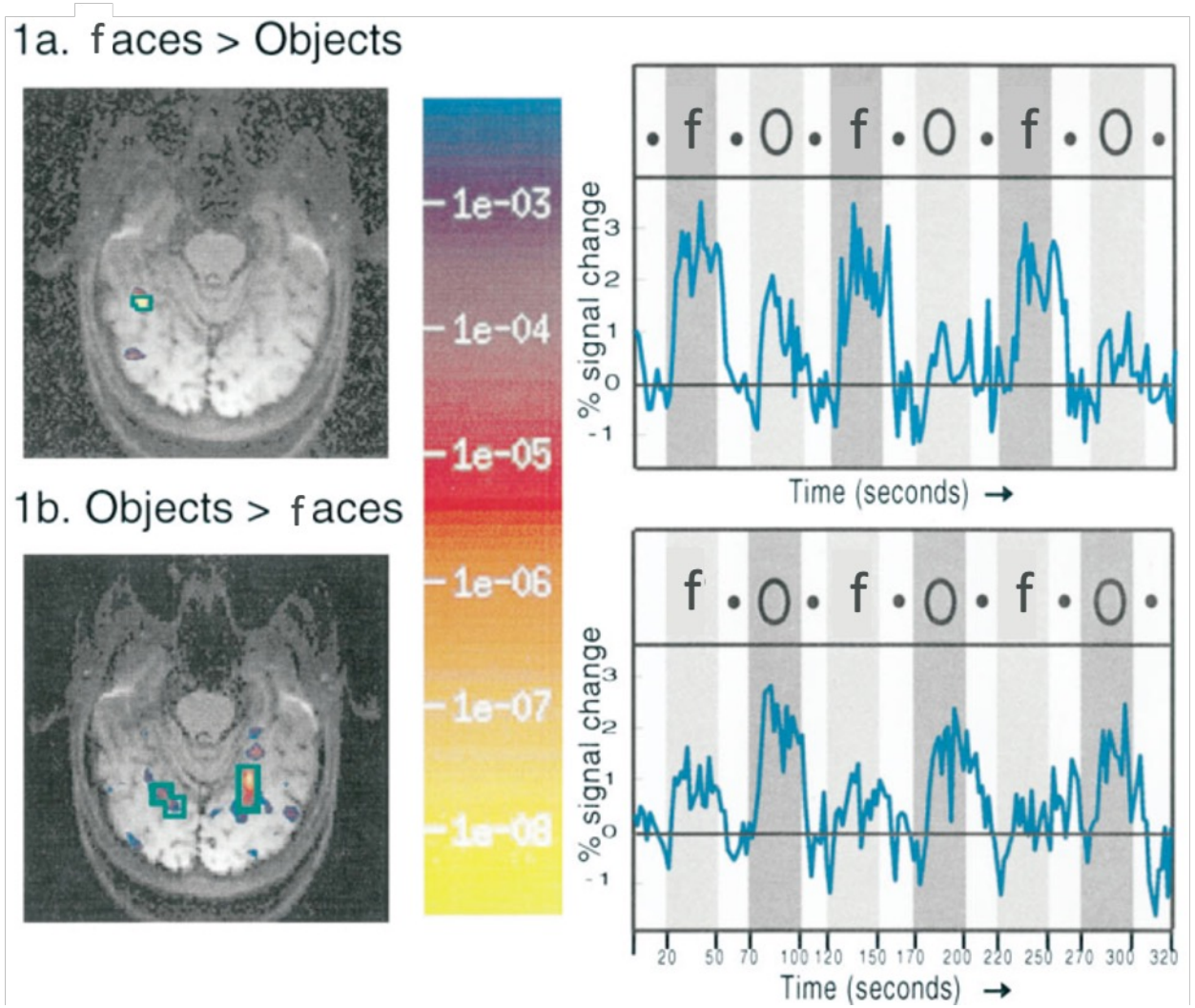
V8: Processes color vision.

LO: Plays a role in recognizing large-scale objects.

Note: A V6 region has been identified only in monkeys.

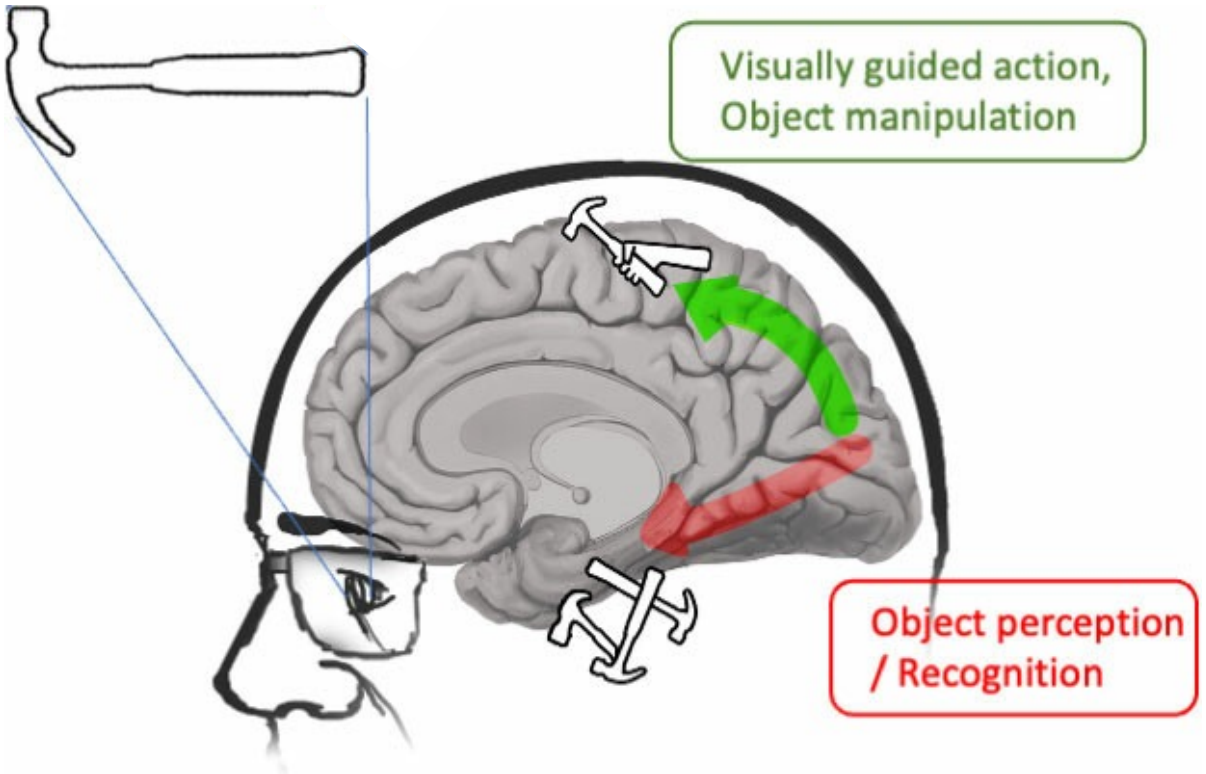
Functional localizer in fMRI (higher-order visual areas)

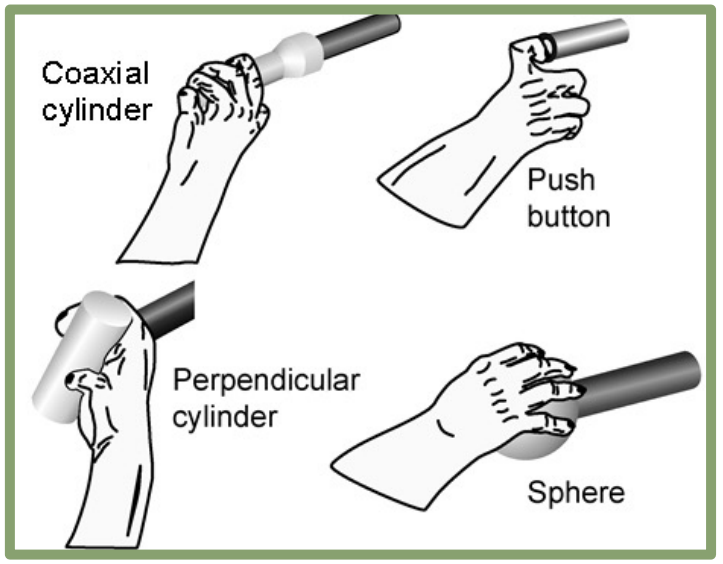




Kanwisher et al., 1997

Higher-order visual areas



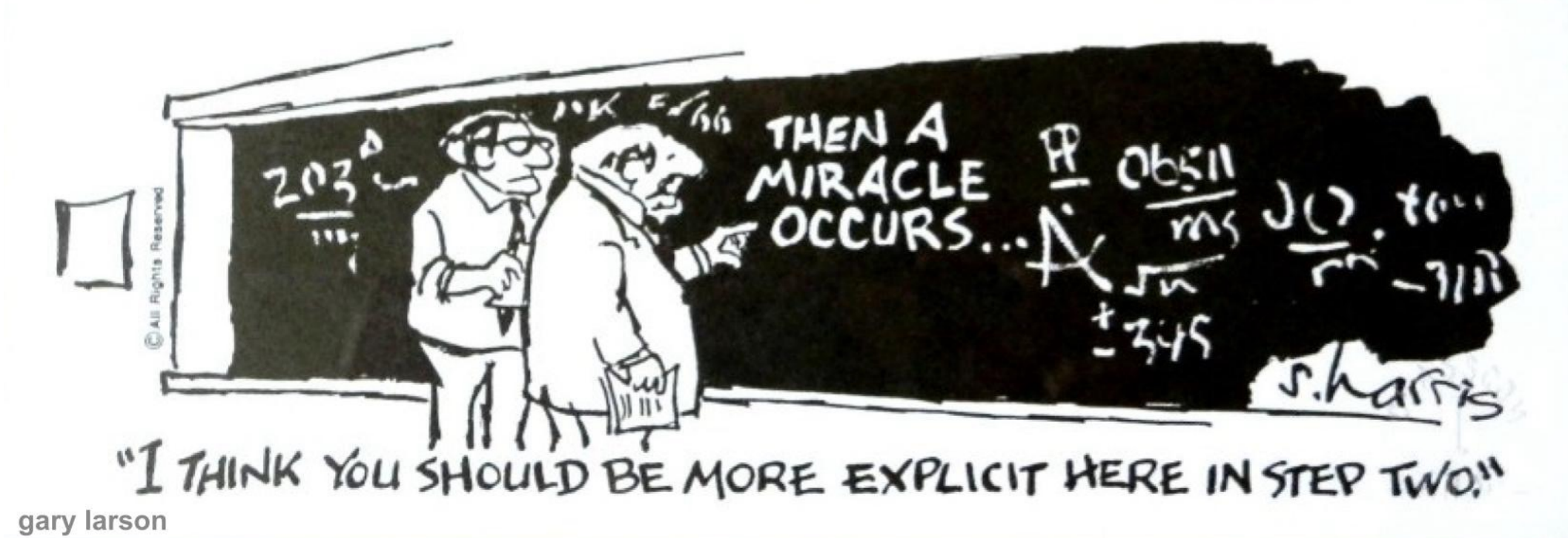


early visual cortex (low-level vision)

- Organized retinotopically
- V1: orientation selective and contrast & spatial frequency sensitive
- Beyond V1: depth, color, & motion perception

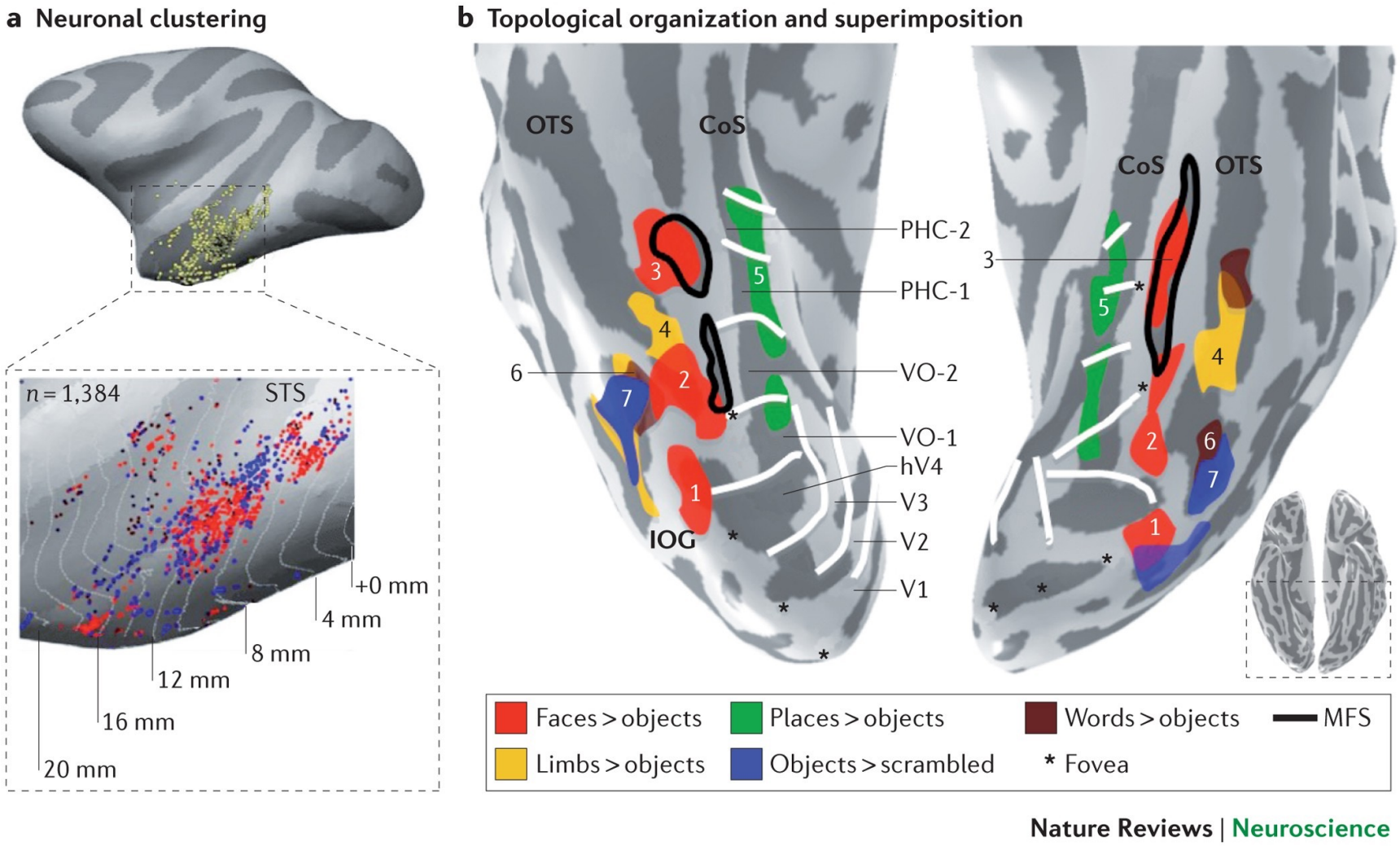
higher-order visual cortex (high-level vision)

- Visually guided actions (dorsal)
- Object recognition (ventral)
- Face recognition (ventral)
- Scene perception (ventral)



early visual cortex (low-level vision)

higher-order visual cortex (high-level vision)

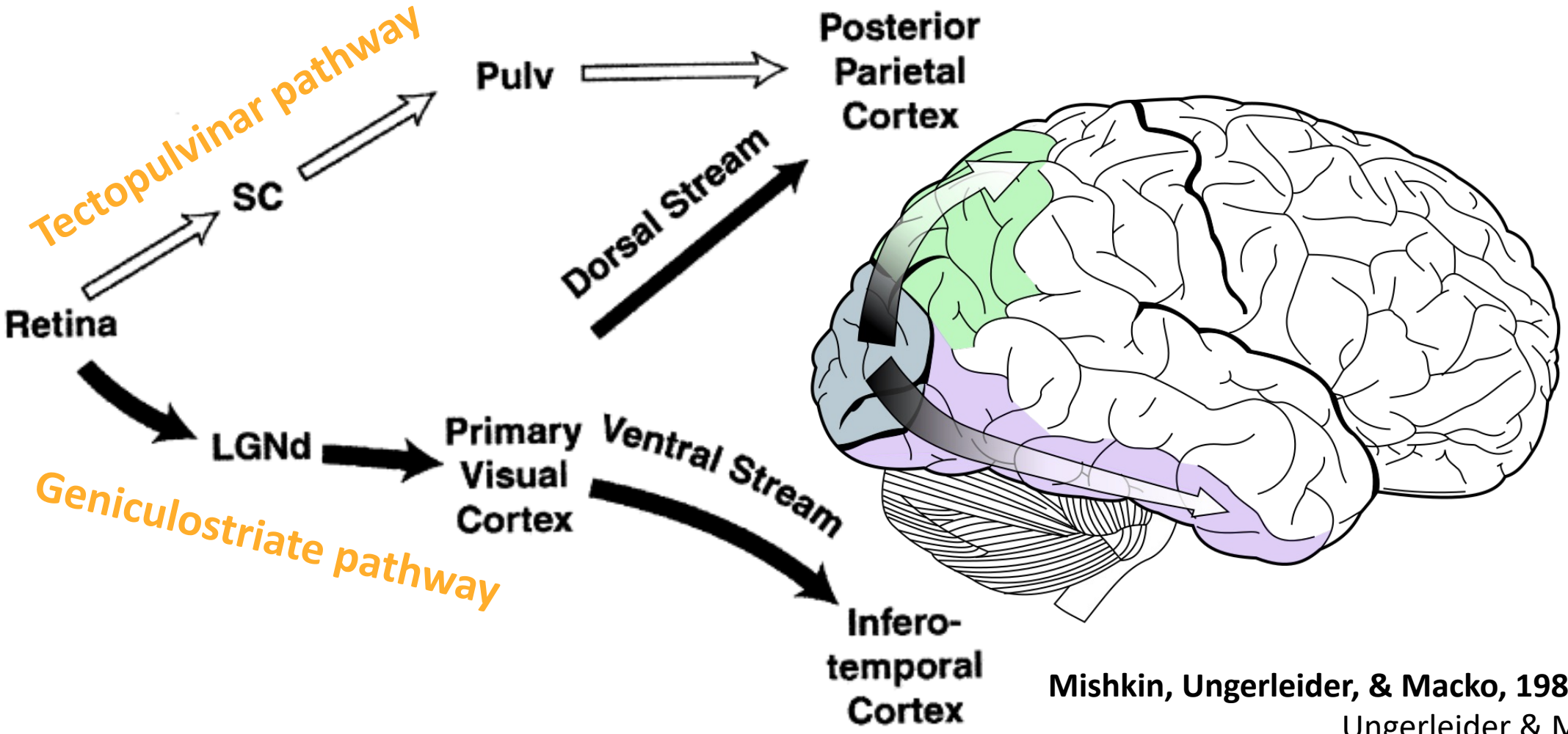


Learning objectives

- Understand the roles of the early visual cortex and higher-order visual areas in visual processing

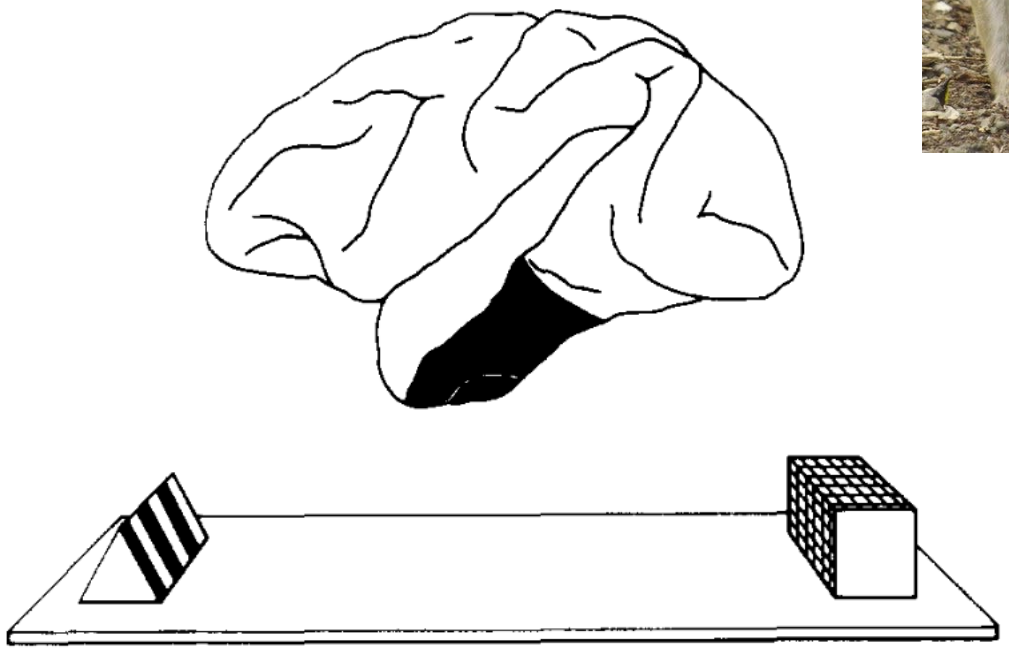
- Explain the functional distinctions between the ventral and dorsal visual pathways (Mishkin, Ungerleider, & Macko, 1983, *TINS*)

Visual Pathways



Mishkin, Ungerleider, & Macko, 1983 (reading 1)
Ungerleider & Mishkin, 1982
Milner & Goodale, 1990

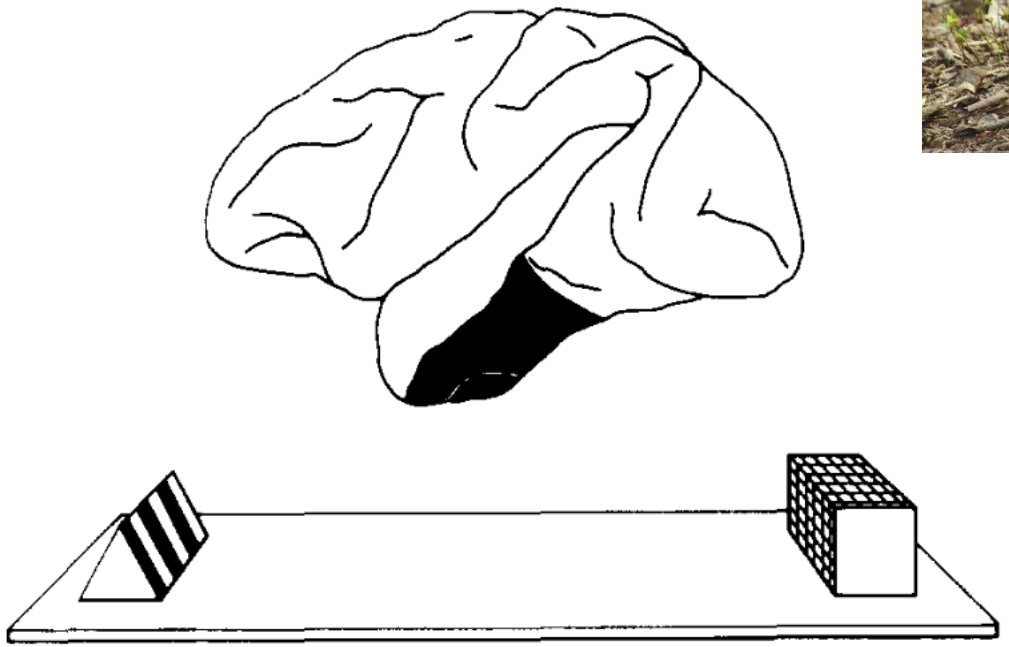
"double dissociation"

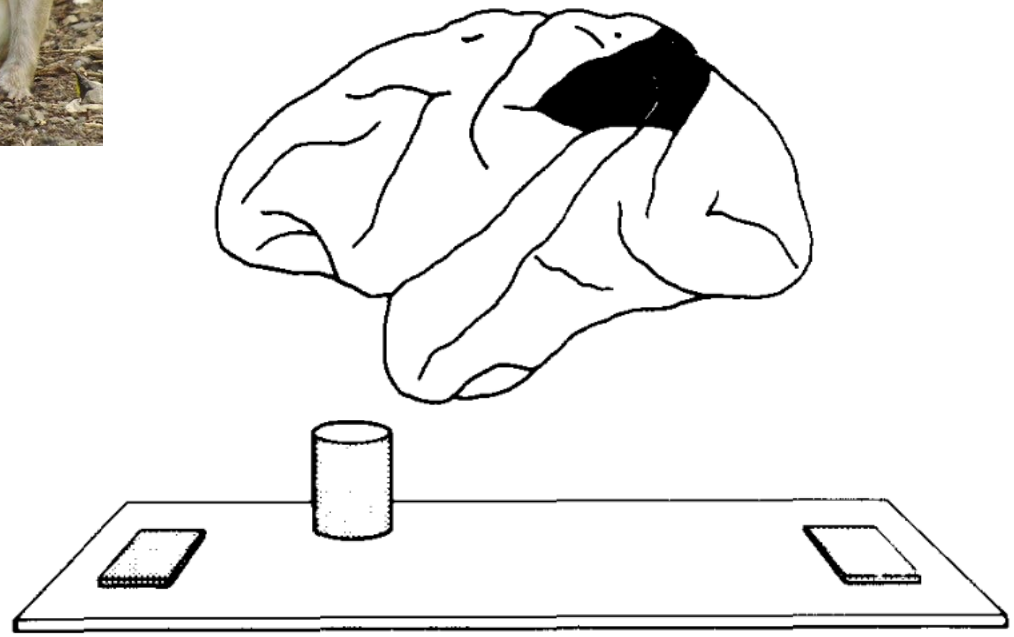


Pohl (1973)

Reading 1: Mishkin, Ungerleider, & Macko (1983)

"double dissociation"





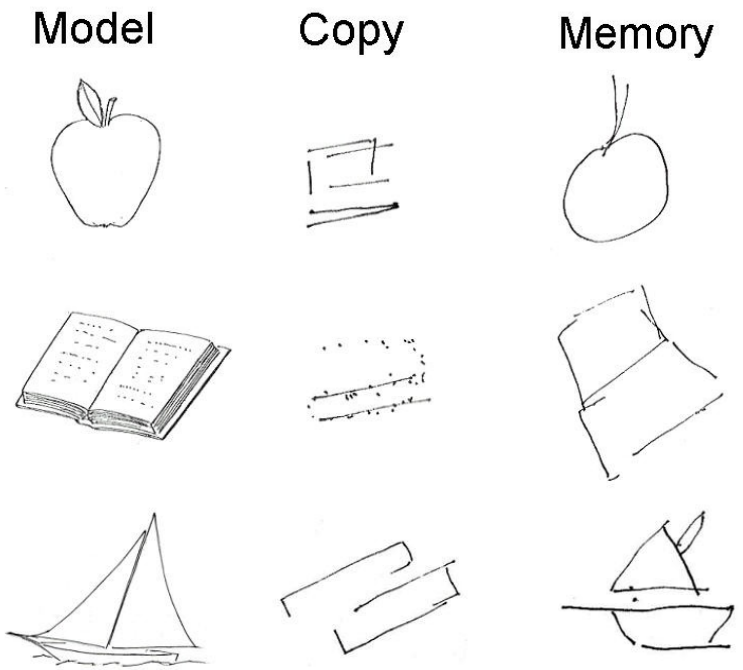
Pohl (1973)

Reading 1: Mishkin, Ungerleider, & Macko (1983)

"double dissociation"

Patient DF

- carbon monoxide poisoning in 1988
- severely damaged the ventral stream, but hardly affected the primary visual cortex.
- ***visual form agnosia*** (unable to identify objects on the basis of their shape, but largely preserved her low-level vision).



Goodale et al., 1991

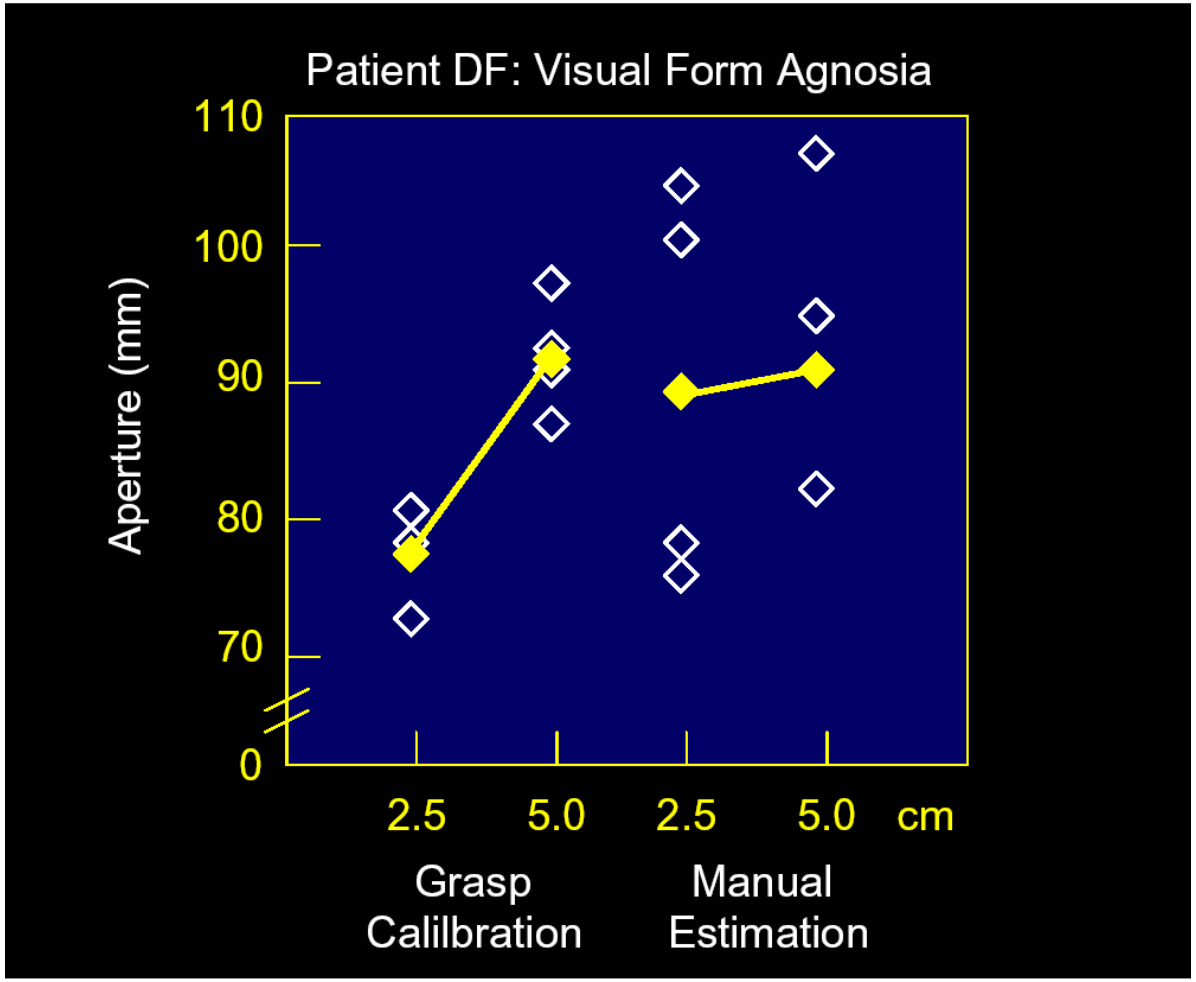
"double dissociation"

Patient RV

- strokes with large bilateral lesions in the occipitoparietal cortex
- severely damaged the dorsal stream
- **optic ataxia** (impaired coordination between visual input and hand movements, preventing patients from reaching and grasping objects)

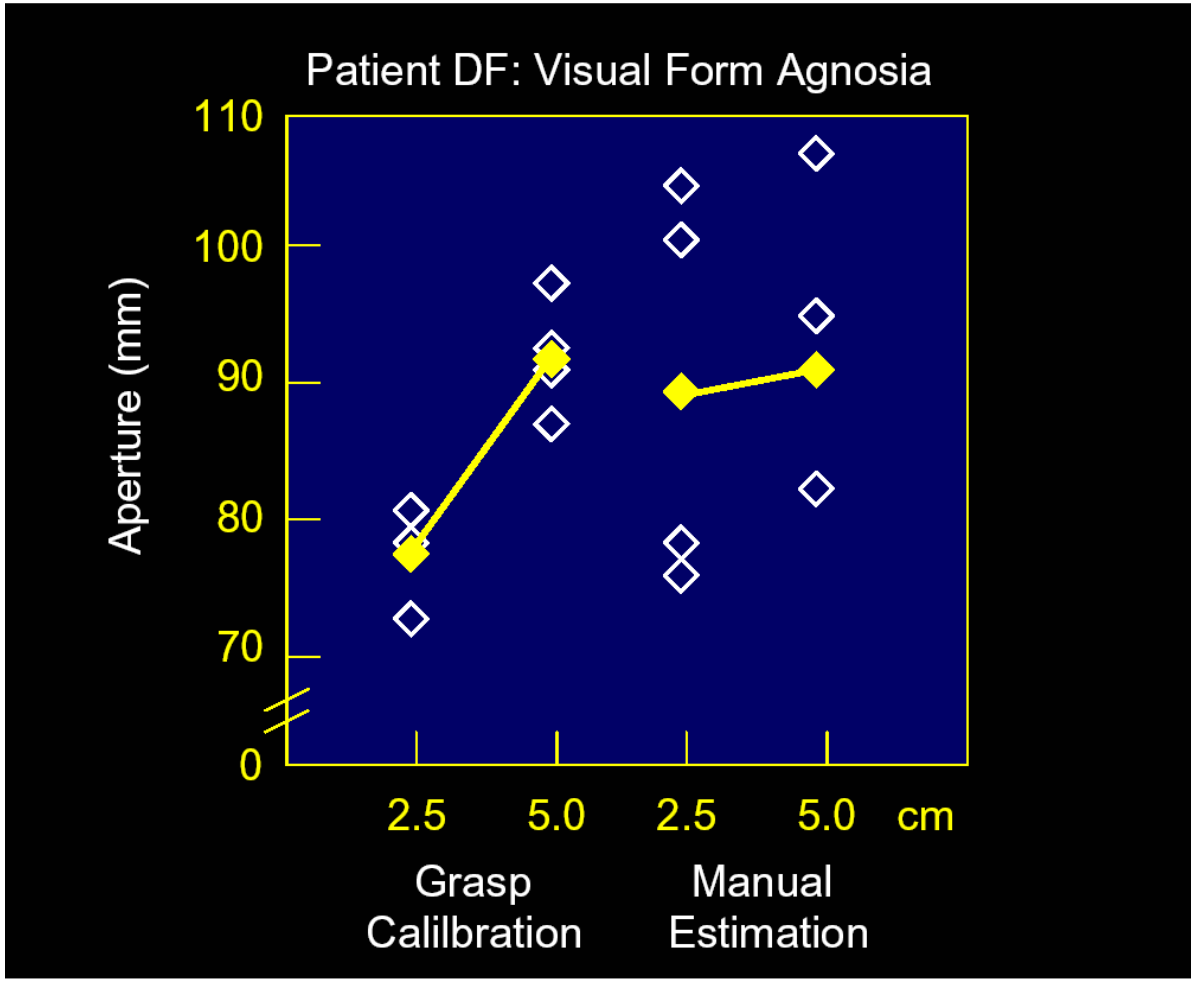
Milner & Goodale (2006)

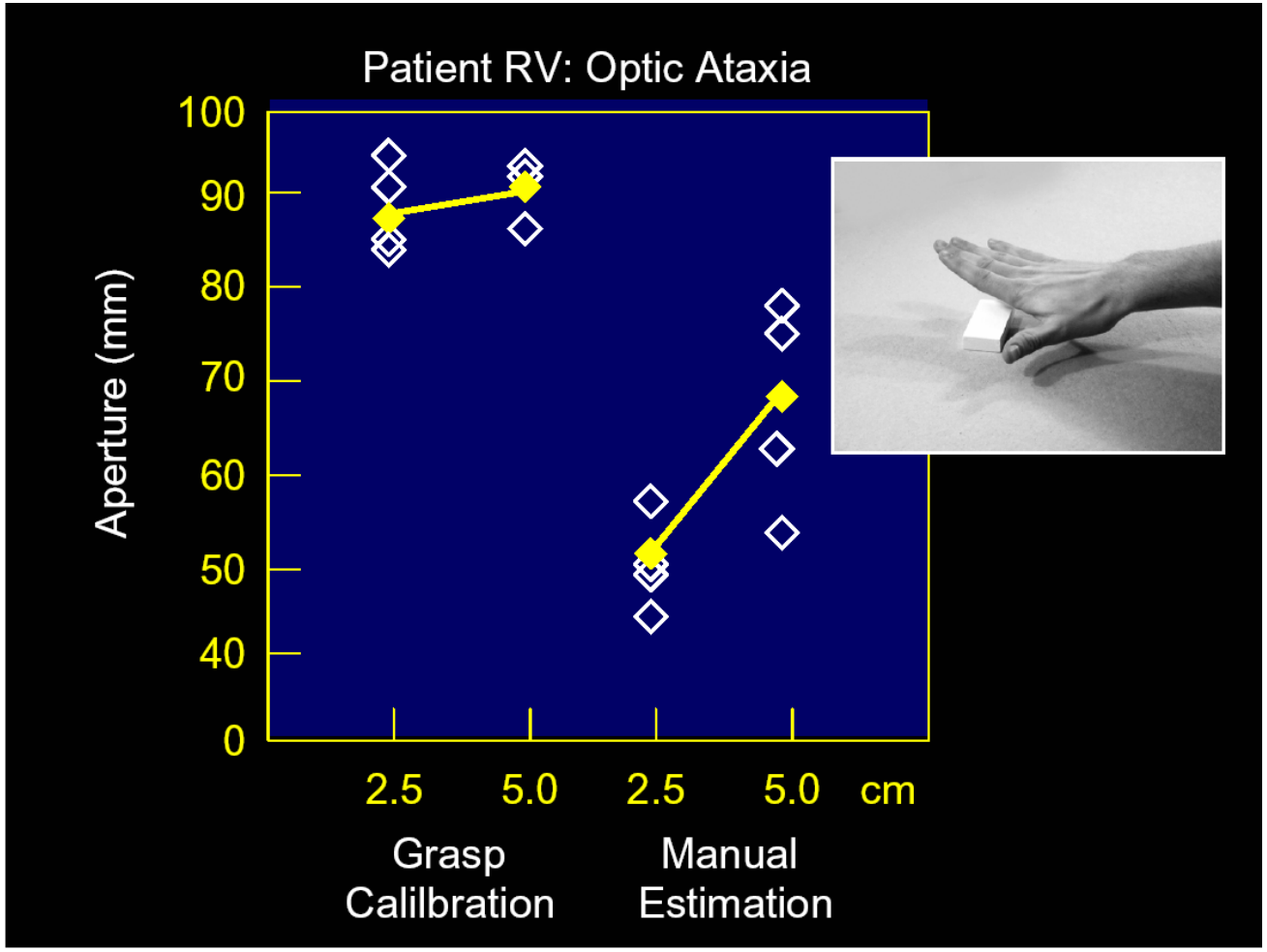
"double dissociation"



Goodale et al., 1991

"double dissociation"

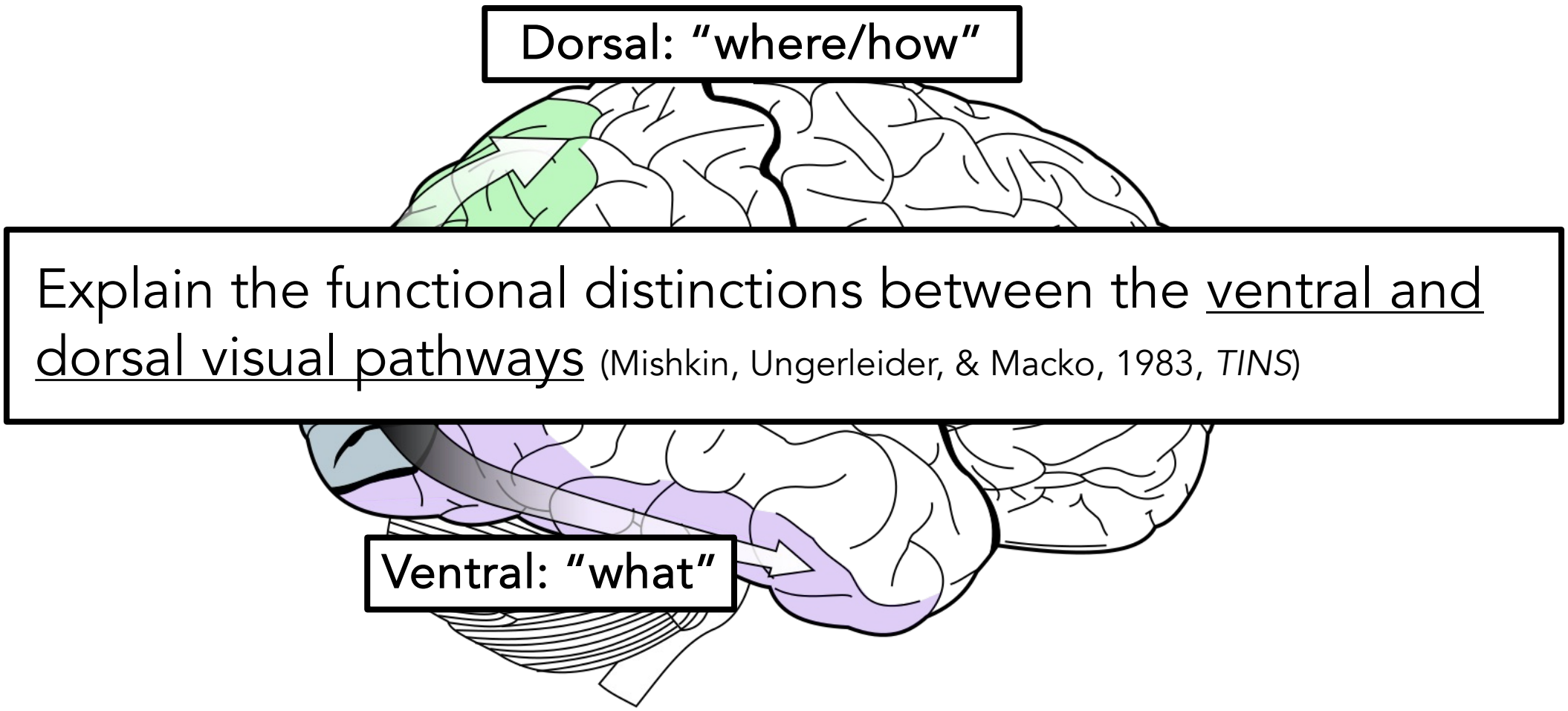




Dorsal: "Where" → "How"

Goodale et al., 1991

Cortical Visual Pathways



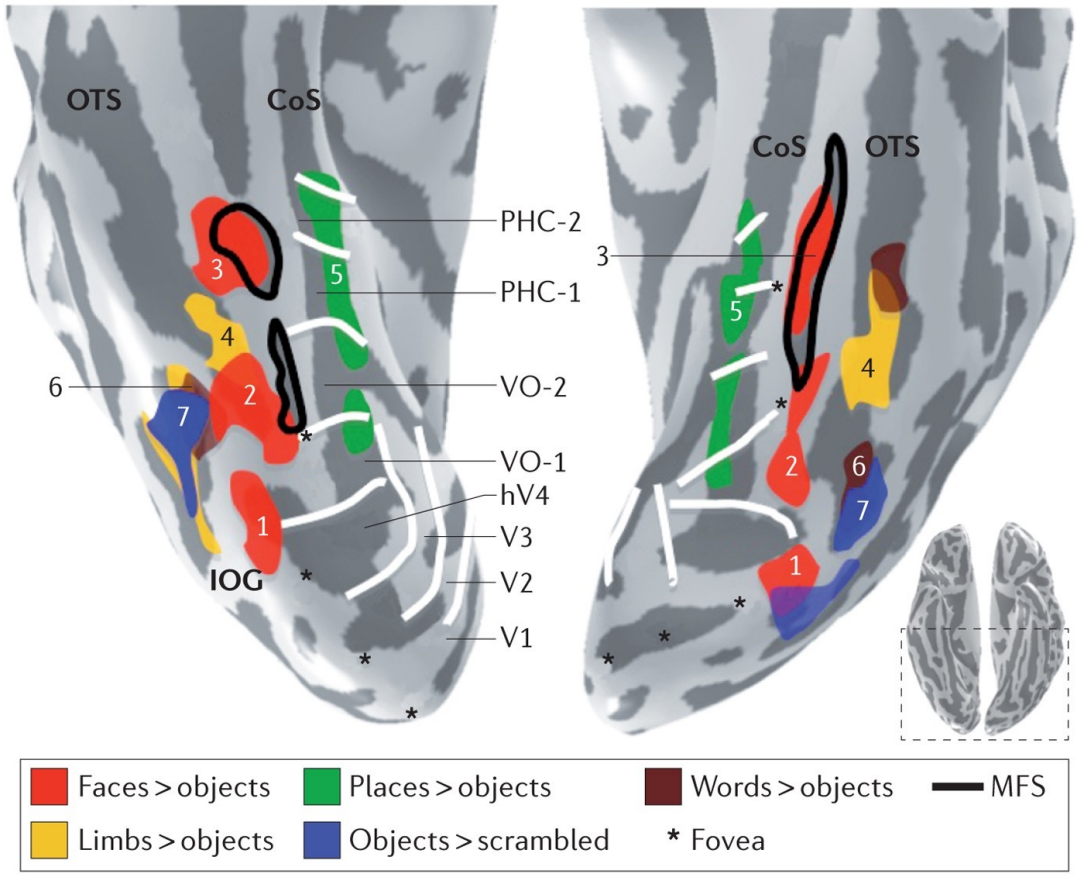
Explain the functional distinctions between the ventral and dorsal visual pathways (Mishkin, Ungerleider, & Macko, 1983, *TINS*)

Ungerleider & Mishkin, 1982
Reading 1: Mishkin, Ungerleider, & Macko, 1983
Milner & Goodale, 1990

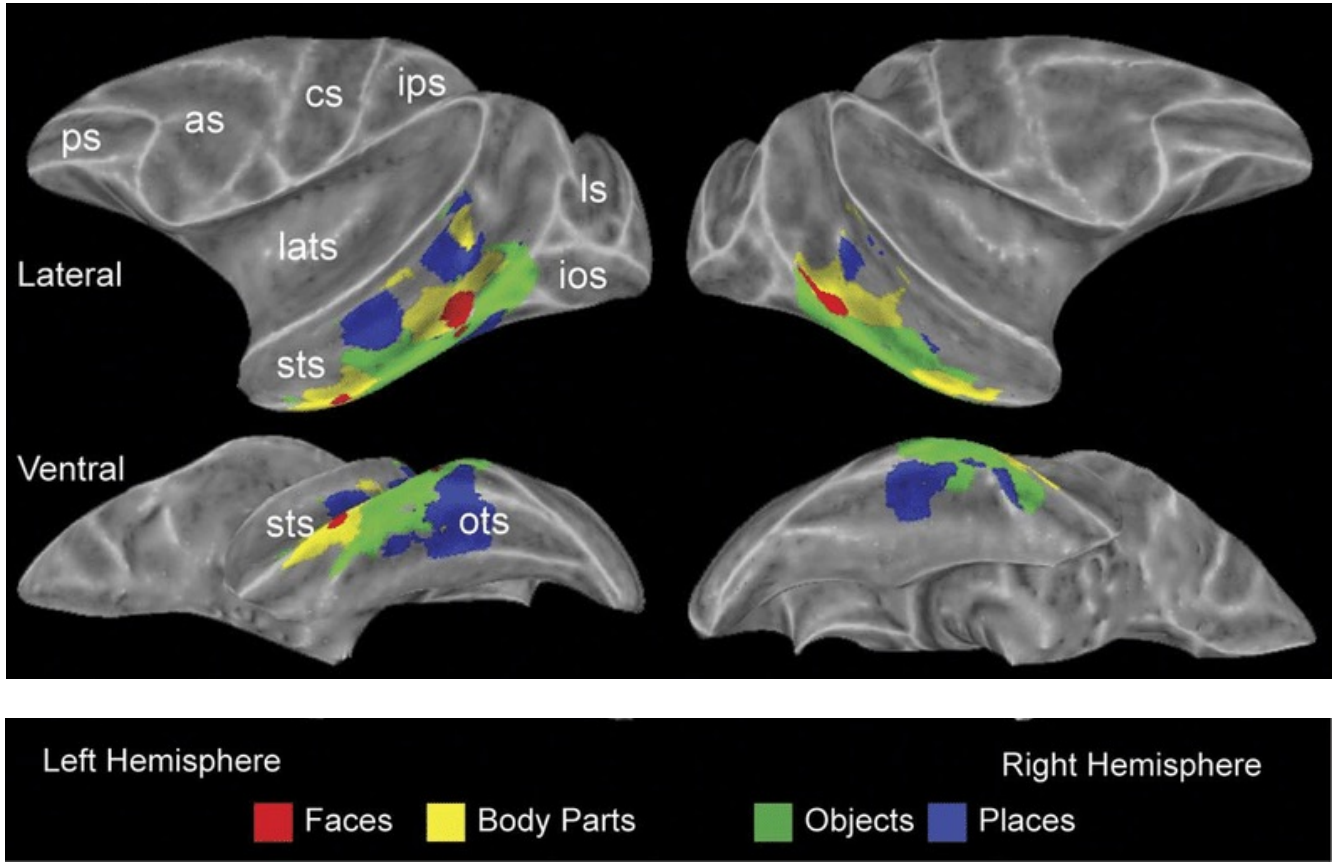
Learning objectives

- Understand the roles of the early visual cortex and higher-order visual areas in visual processing
- Explain the functional distinctions between the ventral and dorsal visual pathways (Mishkin, Ungerleider, & Macko, 1983, *TINS*)
- **Evaluate the evidence in the debate on the development of category selectivity in the ventral pathway** (Arcaro & Livingstone, 2021, *NRN*)

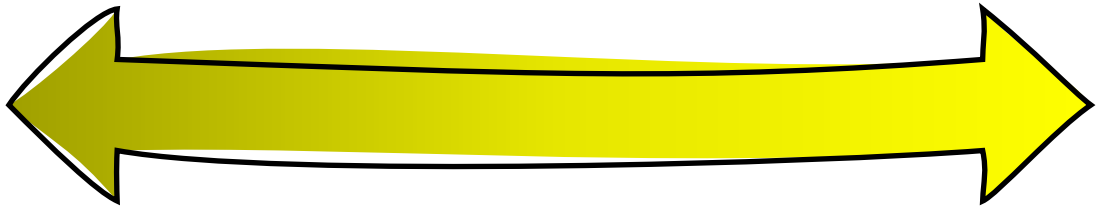
Category selective domains in humans and monkeys



Nature Reviews | Neuroscience



"top-down model"
Innatist



"Bottom-up model"
Experience x domain-general architecture

Our brains evolved specialized circuitry to recognize biologically important object categories

- stereotyped locations in both humans & monkeys
- biologically important object categories (faces, bodies, food, tools, & places)

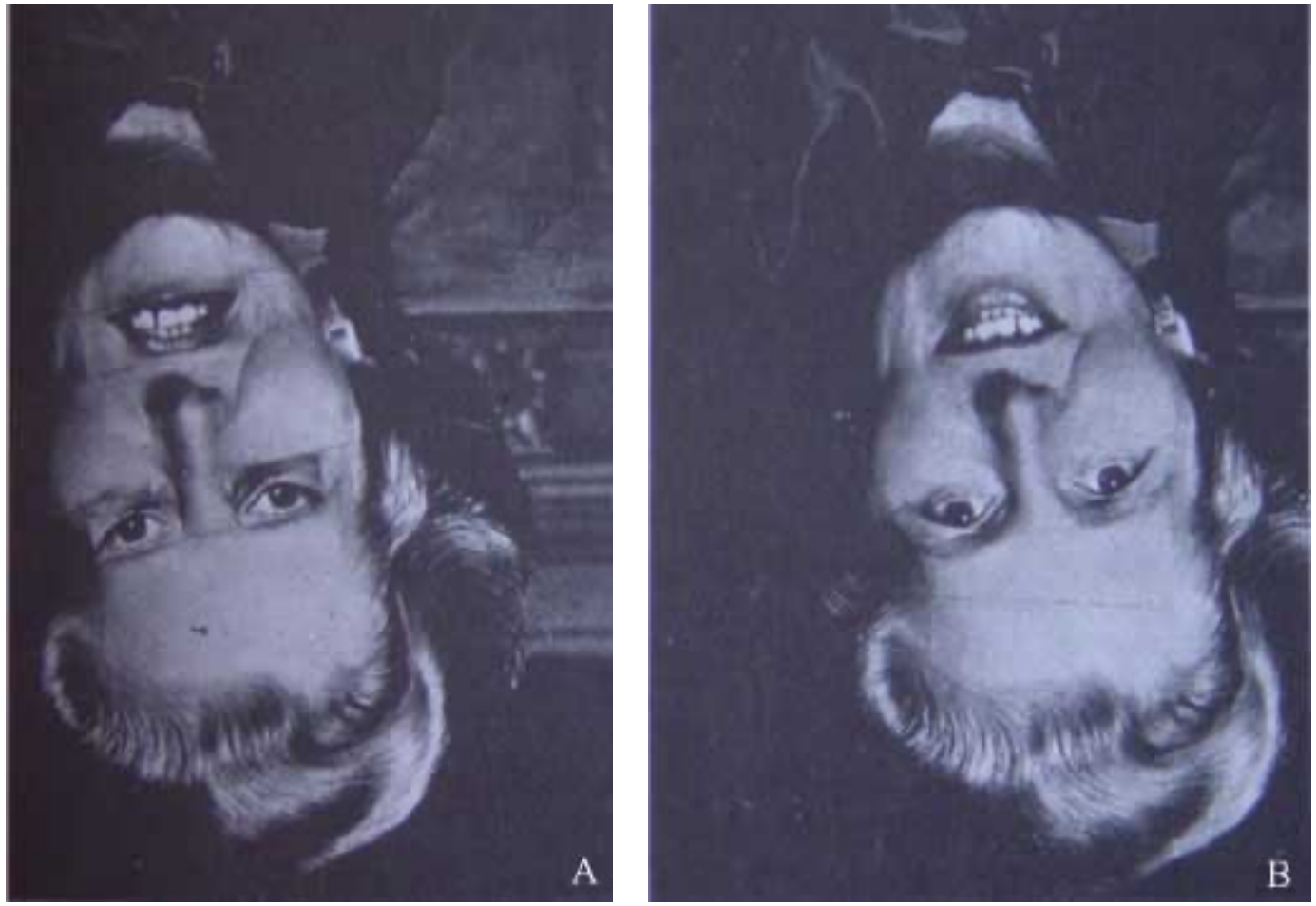
Specialized domains reflect how we learn to recognize the things we encounter

- a domain for text is evolutionarily implausible
- cortical recycling of a domain that was previously "for" something else

Are faces special?

1. Face inversion effect

The ‘Thatcher Illusion’



(Thomson, 1980)

1. Face inversion effect

The ‘Thatcher Illusion’

(Thomson, 1980)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Mind

Man who sees upside down provides clues on how we process faces

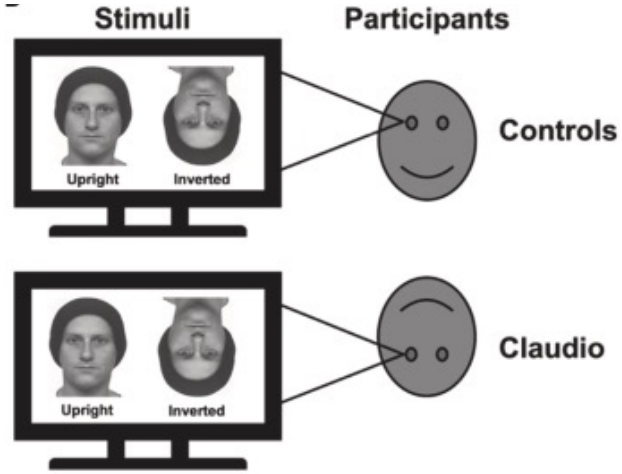
A man with a condition that has rotated his head backwards can identify upright and inverted faces with similar accuracy, suggesting that facial processing skills are based on experience and evolutionary factors

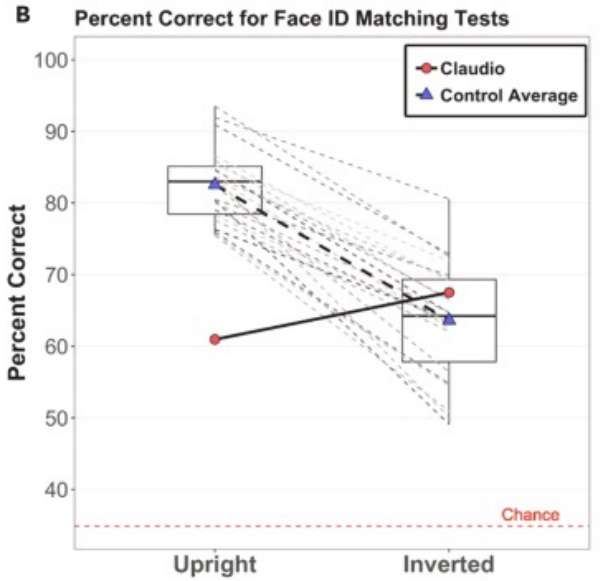
By Grace Wade

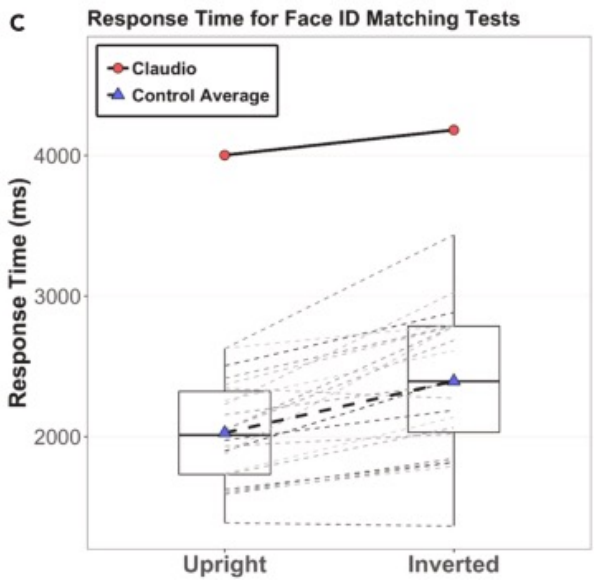
22 September 2023

Claudio Oliveira was born with a joint condition that restricted the range of motion in the joints of his neck

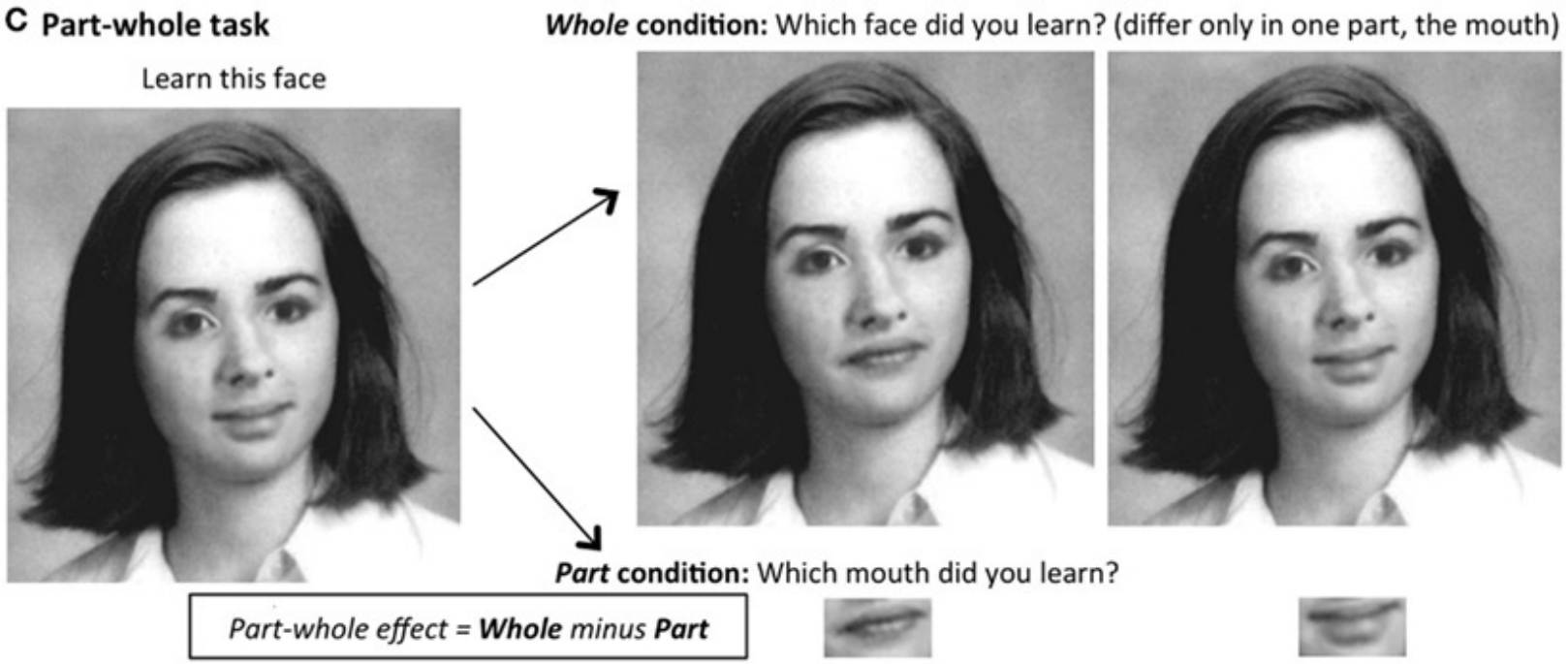
Brad Duchaine







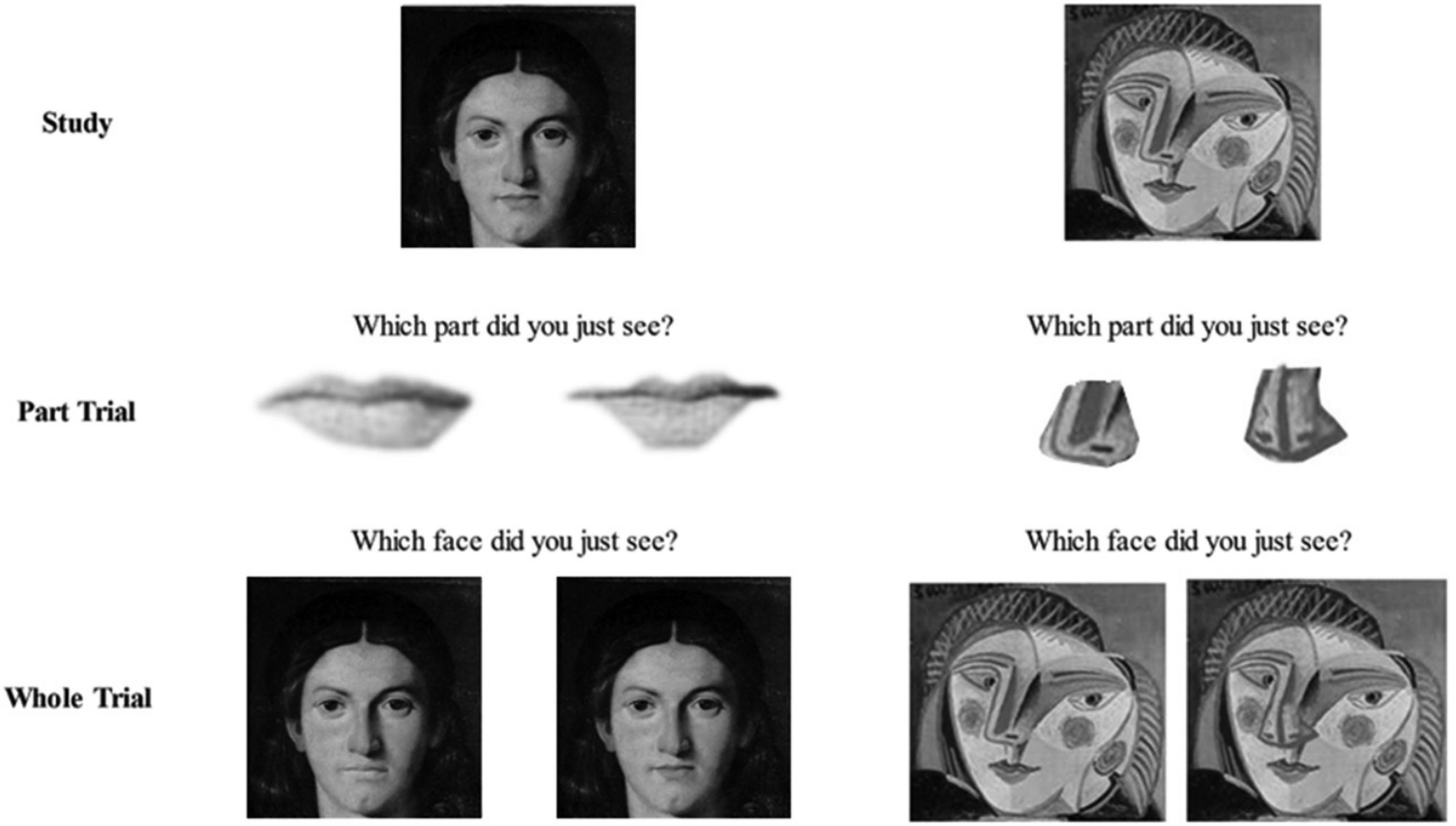
2. Part-whole effect



- Study a whole face
- Recognize facial features
  embedded in a whole face or presented in isolation
- Holistic processing = better performance when the features are presented within the context of a face than in isolation

2. Part-whole effect

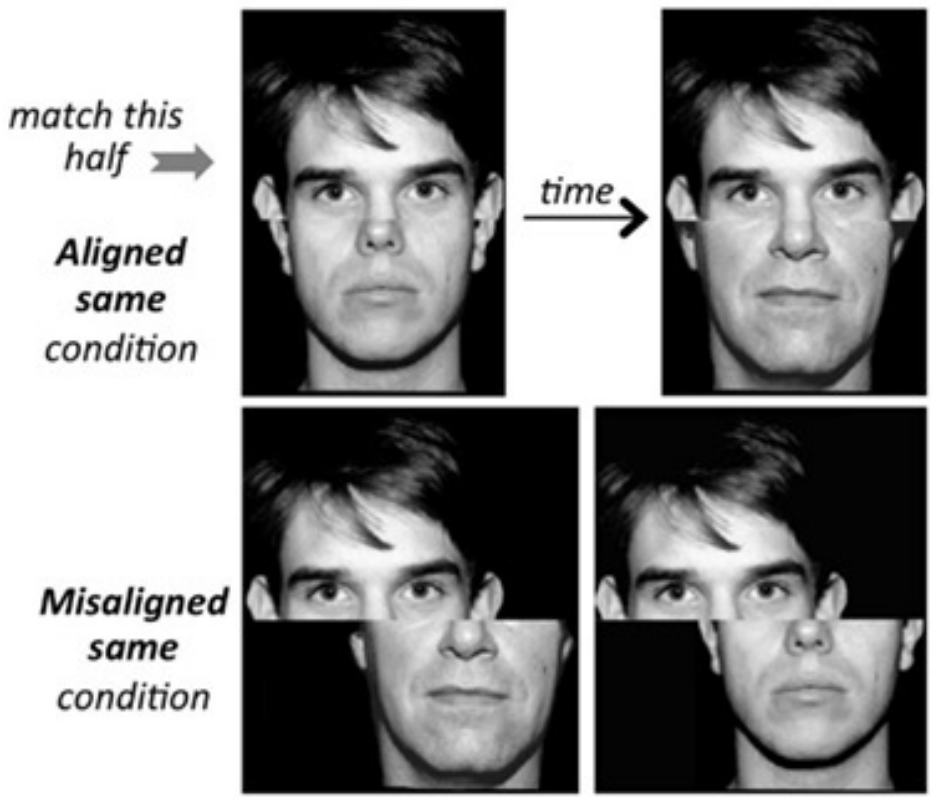
Figure 1
The Part–Whole Task Procedure



Note. The left panel shows an example of the part trial (mouth) and the whole trial (mouth) for renaissance; the right panel shows an example of part trial (nose) and whole trial (nose) for cubism.

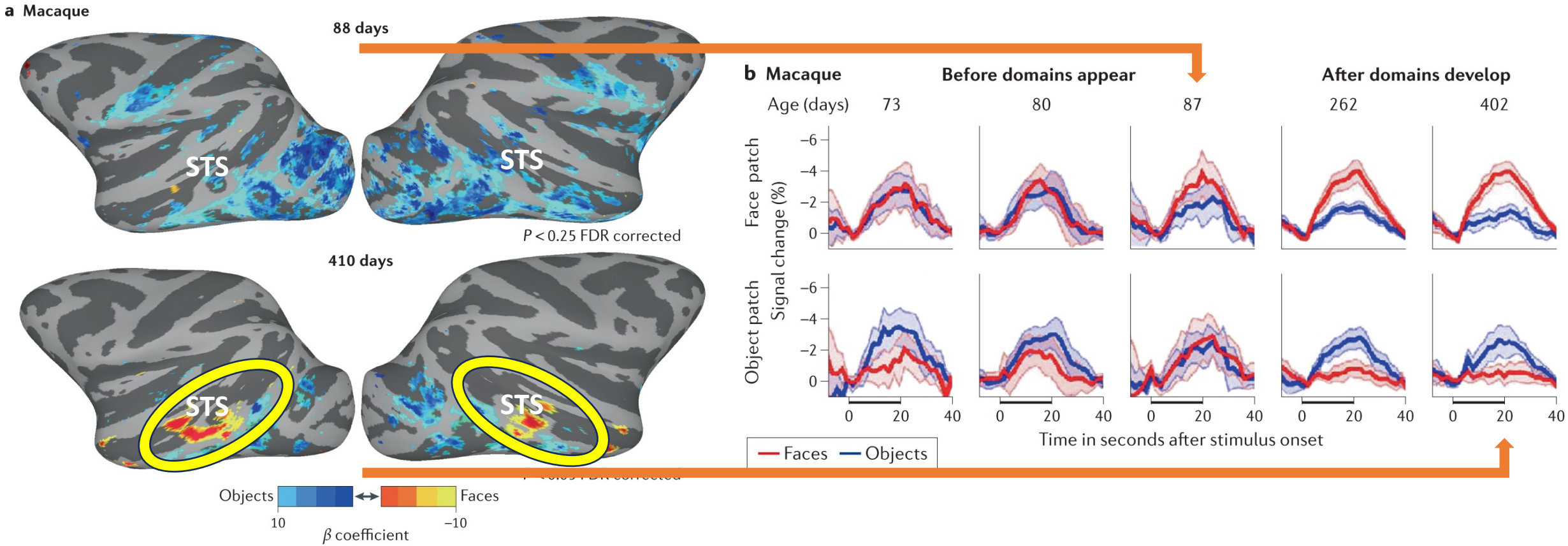
Ventura*, Liu* et al. (2023). *Psychology of Aesthetics, Creativity, and the Arts.*

3. Composite effect



- A composite face = half of one face + half of a second face
- Clear instruction to ignore part of the face
- Holistic processing = better performance when the top and bottom halves are misaligned than when they are aligned

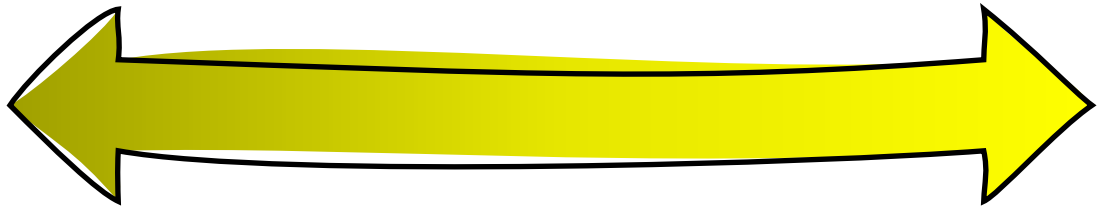
Development of face selectivity in inferotemporal cortex (IT)



Arcaro, Schade, Vincent, Ponce, & Livingstone (2017). *Nature neuroscience*.

What condition is sufficient for the development of a category-selective domain?

"top-down model"
Innatist model



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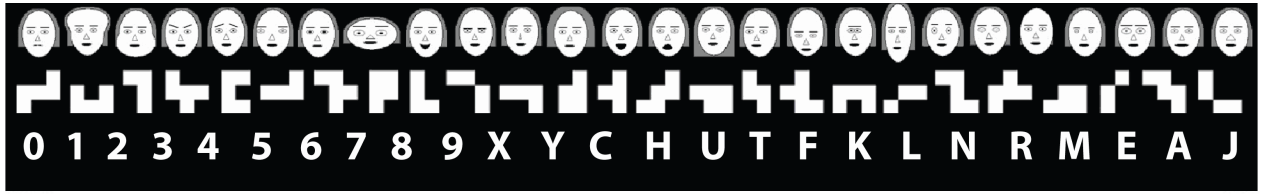
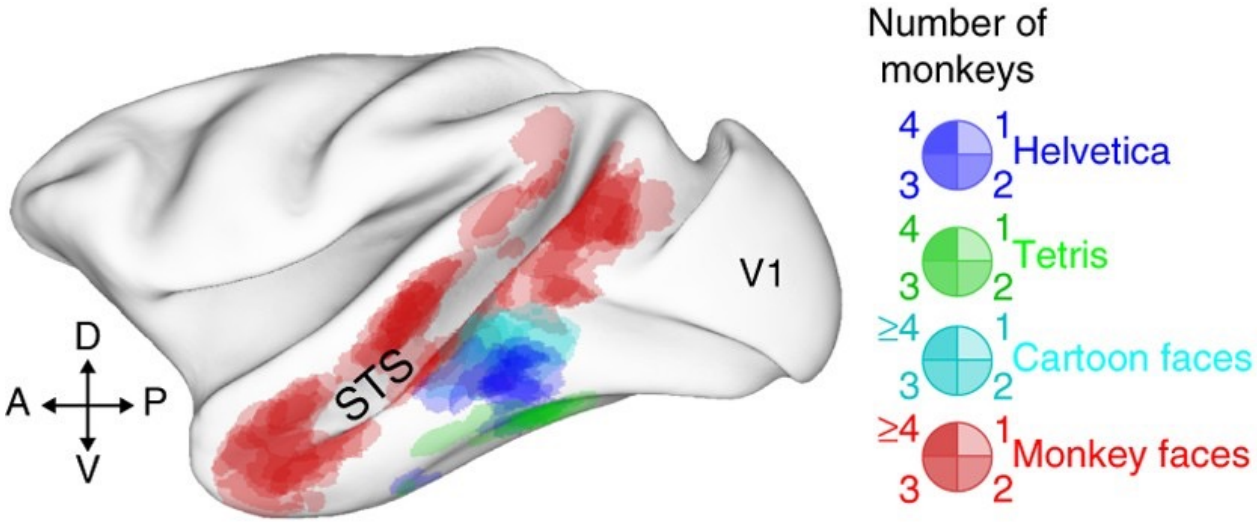
Development of word selectivity in inferotemporal cortex (IT)

- In humans, the development of VWFA requires experience (it doesn't develop unless an individual has learned to read)
- VWFA in Monkeys?





Arcaro MJ, et al. 2019. *Annu. Rev. Vis. Sci.* 5:341–72

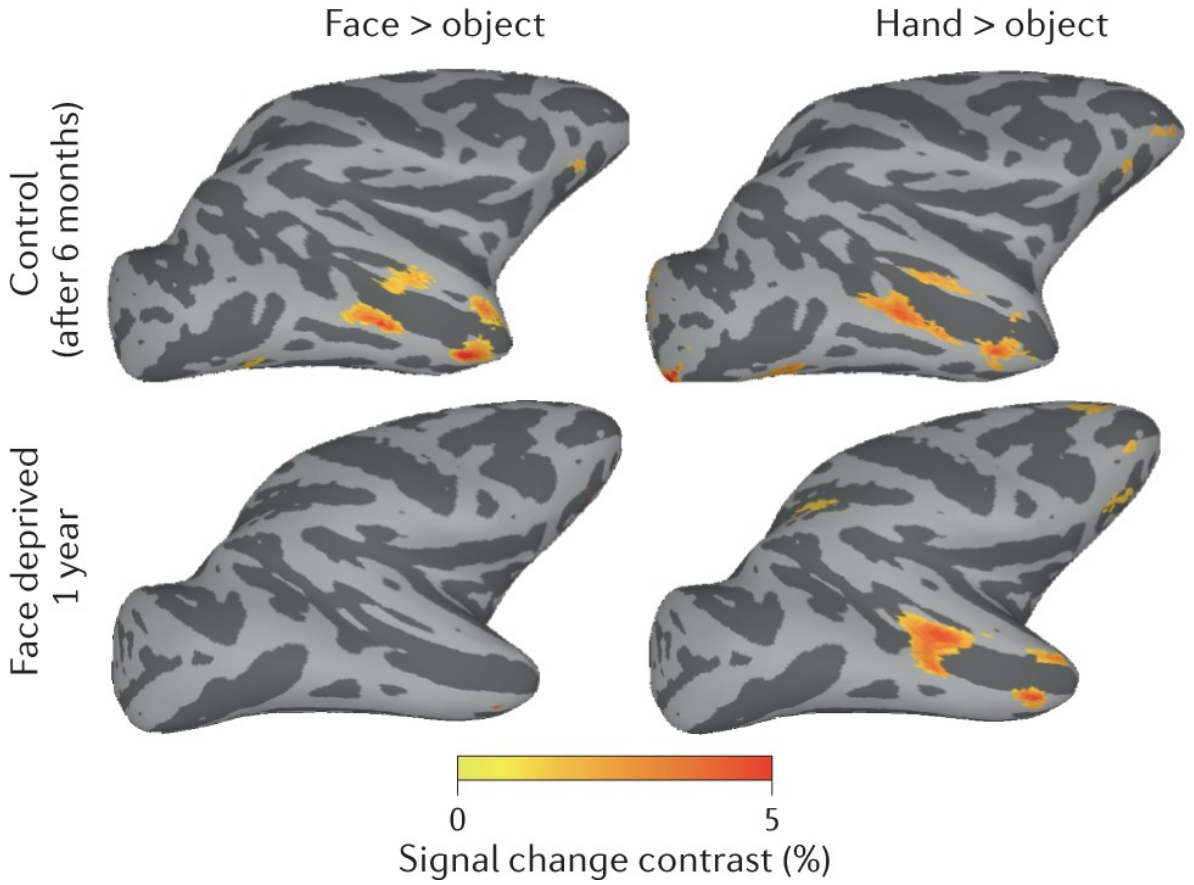
Srihasam et al. (2012). *Neuron.*
Srihasam et al. (2014). *Nature neuroscience.*

What condition is sufficient for the development of a category-selective domain?

- Intensive experience alone is sufficient to produce a category-selective domain (Srihasam et al., 2012; 2014)

What condition is necessary for the development of a category-selective domain?

Experience is necessary for developing domains



Arcaro, Schade, Vincent, Ponce, & Livingstone (2017). *Nature neuroscience*.

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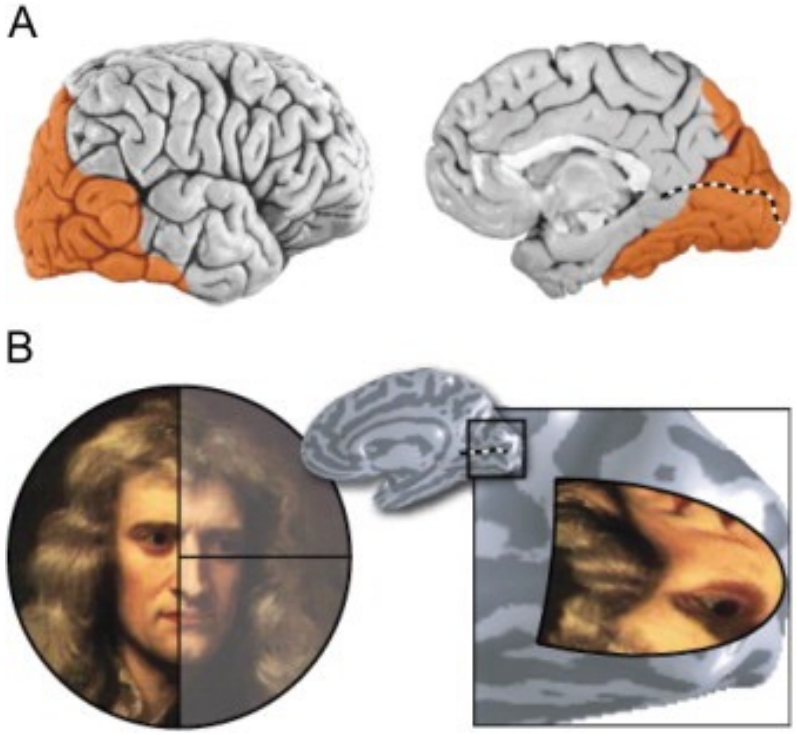
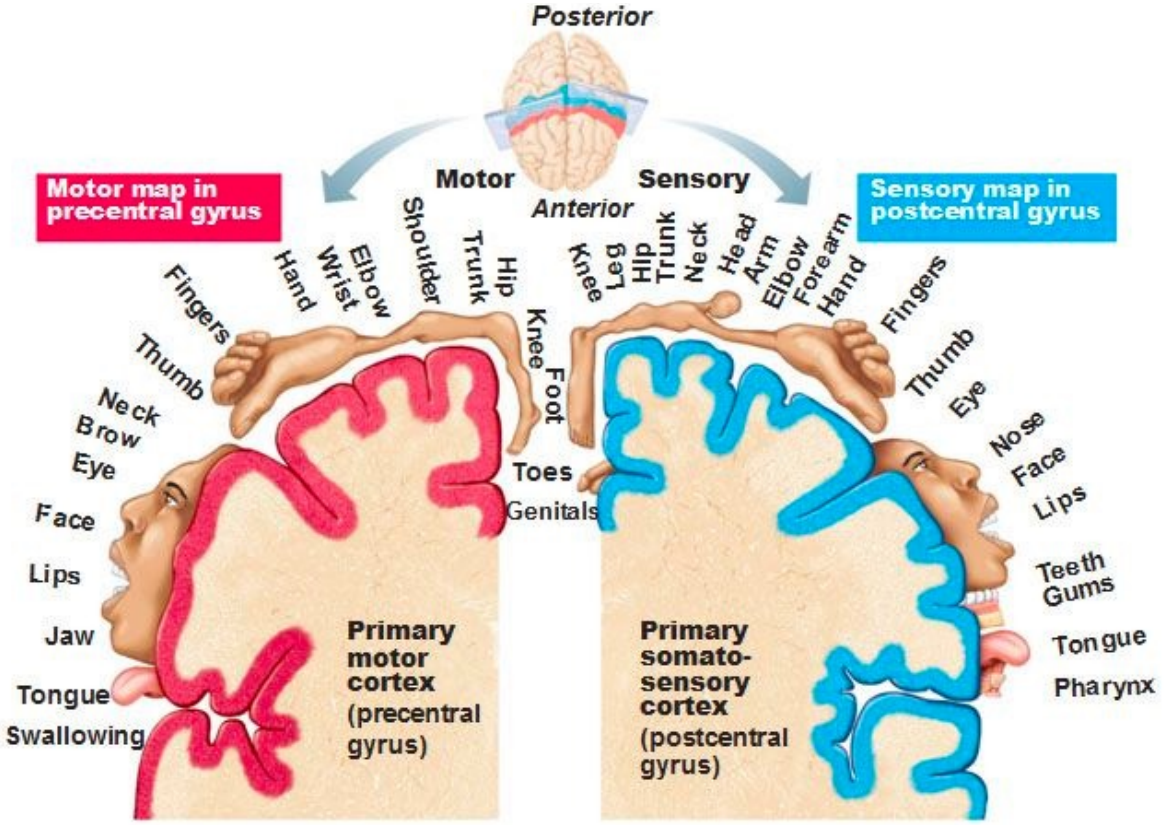
Topographic organization in the brain

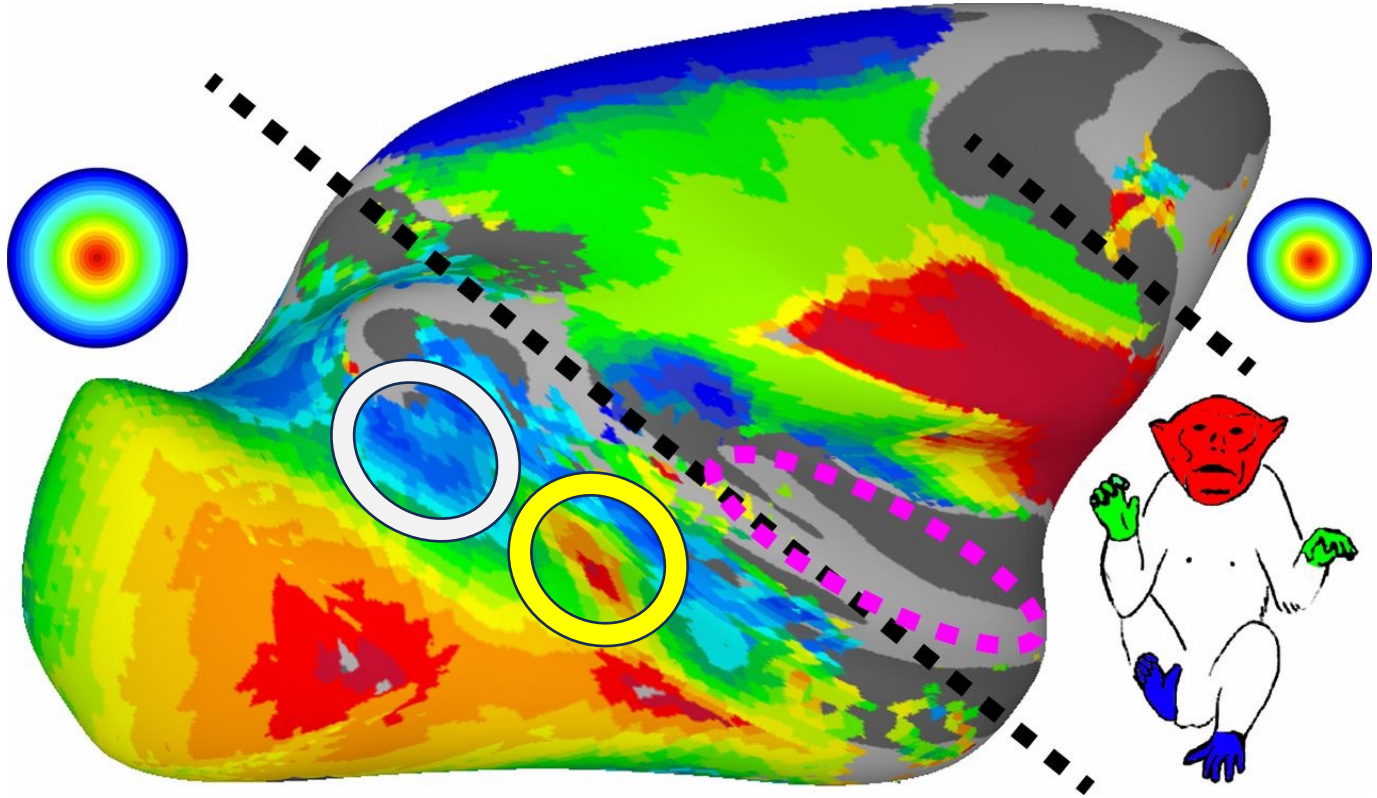
- spatially adjacent stimuli on sensory receptor surfaces are represented in adjacent positions in the cortex.





Proto-architecture: topographic maps

somatotopic representations of body surface

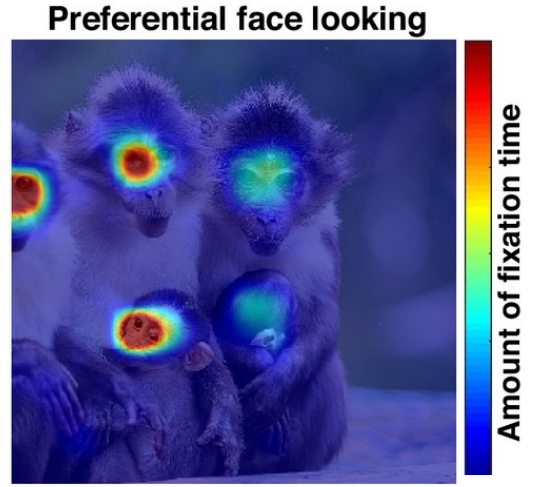


retinotopic representations
of visual space

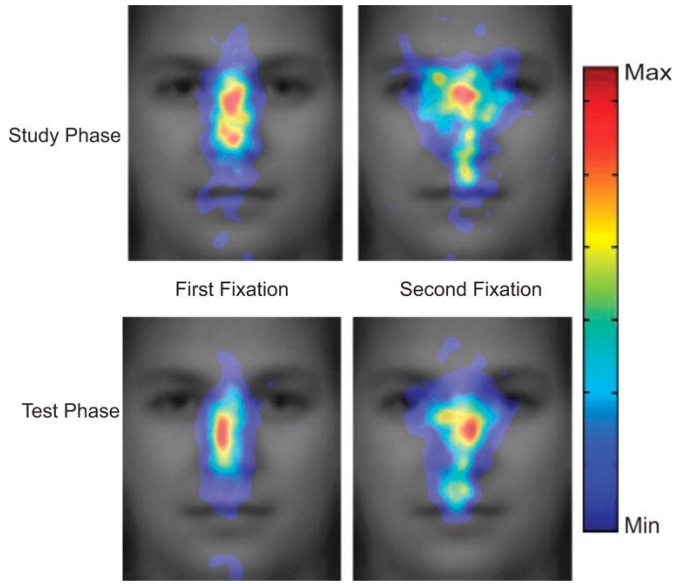
topographic maps precede category selectivity during development!

Observer:

Macaque



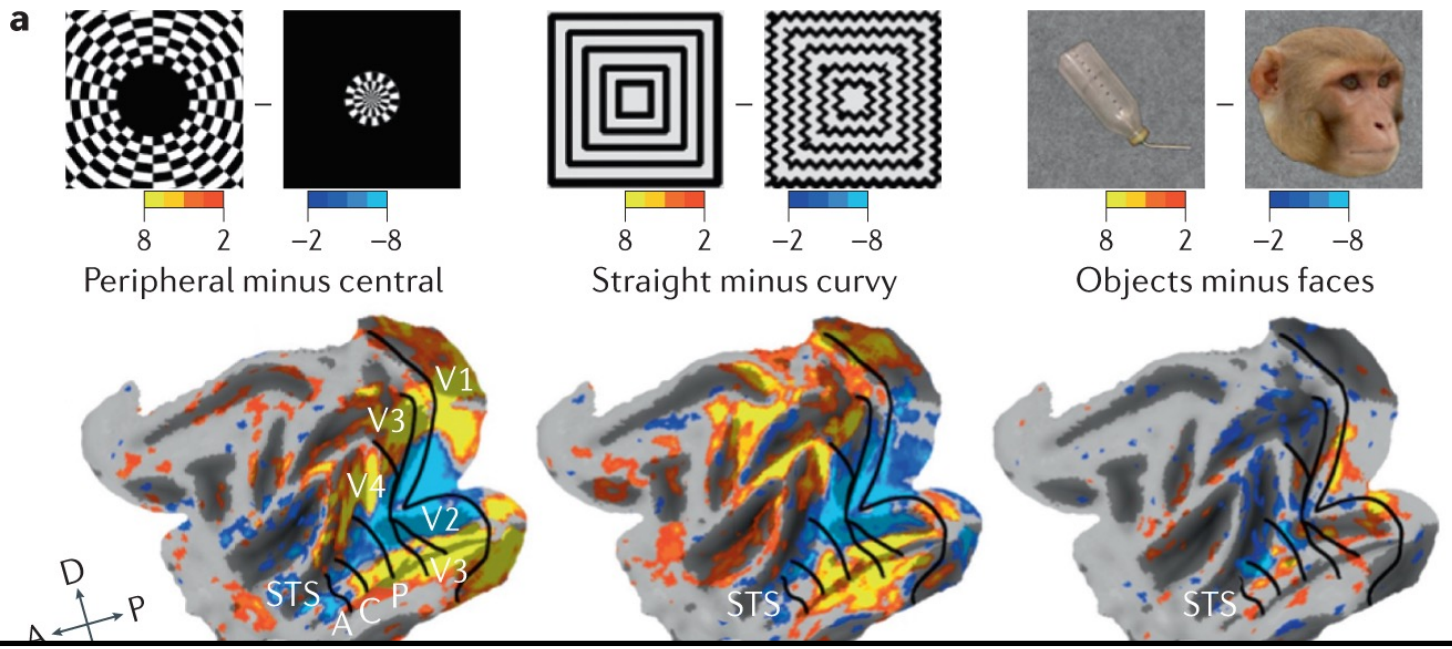
Human



Two fixation suffice in face recognition
(Hsiao & Cottrell, 2008)

Macaque brain

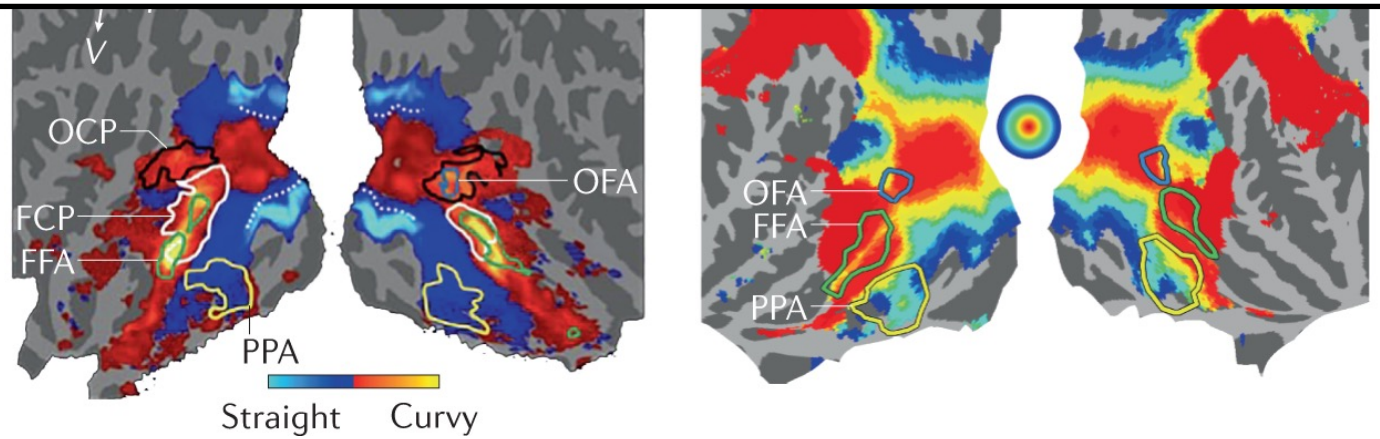
blue regions prefer CVF, curvature, and faces



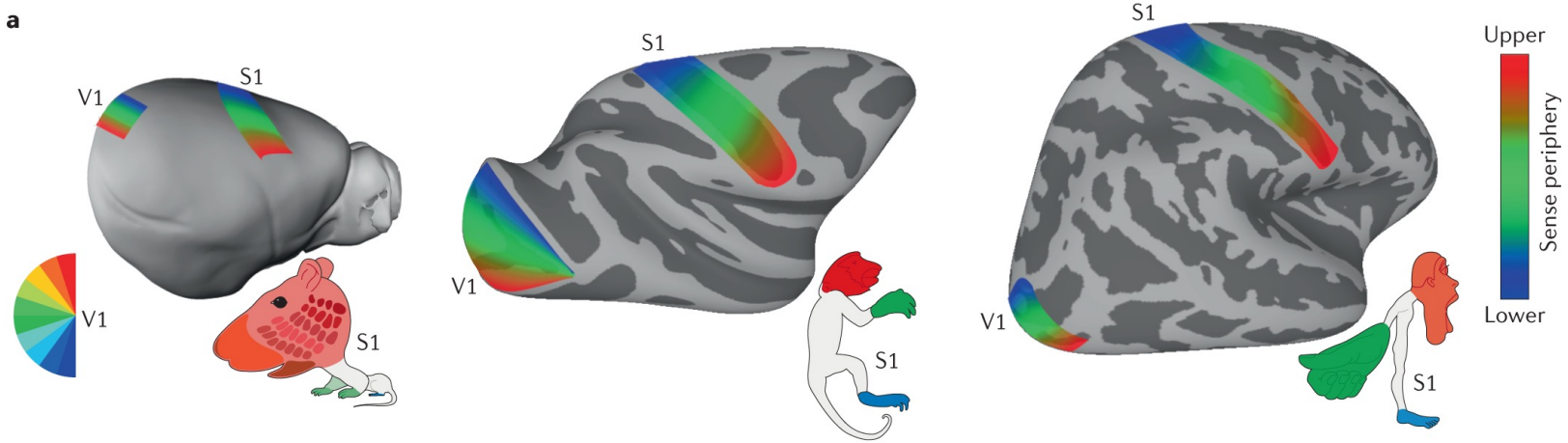
A fine-scale architecture is embedded in a large-scale architecture. Category selectivity cannot be the driving force for curvature or retinotopy, it should be the reverse.

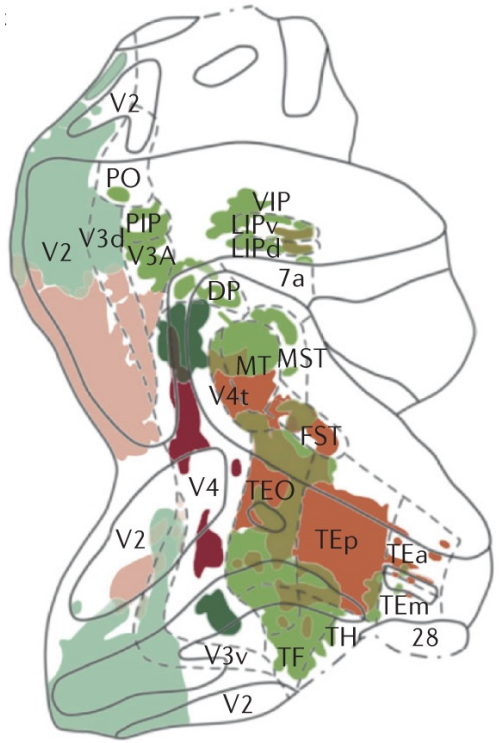
Human brain

red regions prefer curvature and CVF

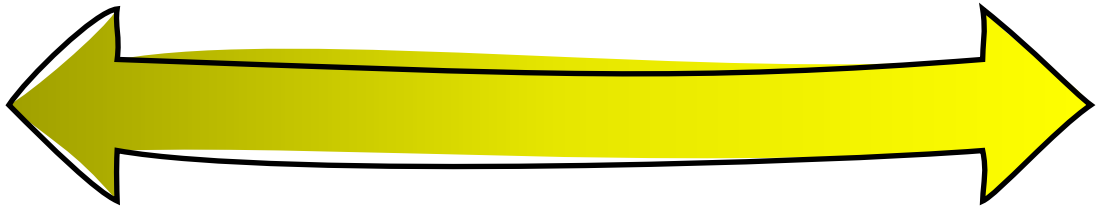


Congruence between sensory maps





"top-down model"
Innatist



"Bottom-up model"
Experience x domain-general architecture

Our brains evolved specialized circuitry to recognize biologically important object categories

- stereotyped locations in both humans & monkeys
- biologically important object categories (faces, bodies, food, tools, & places)

Specialized domains reflect how we learn to recognize the things we encounter

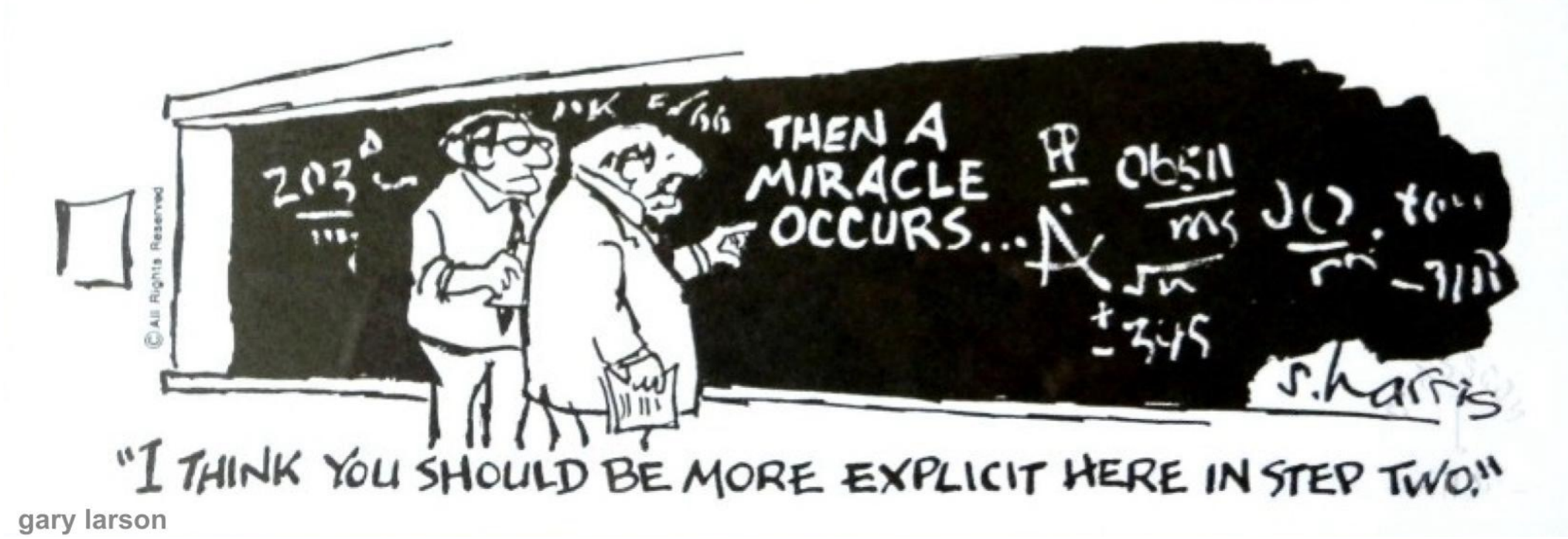
- a domain for text is evolutionarily implausible
- cortical recycling of a domain that was previously "for" something else

early visual cortex (low-level vision)

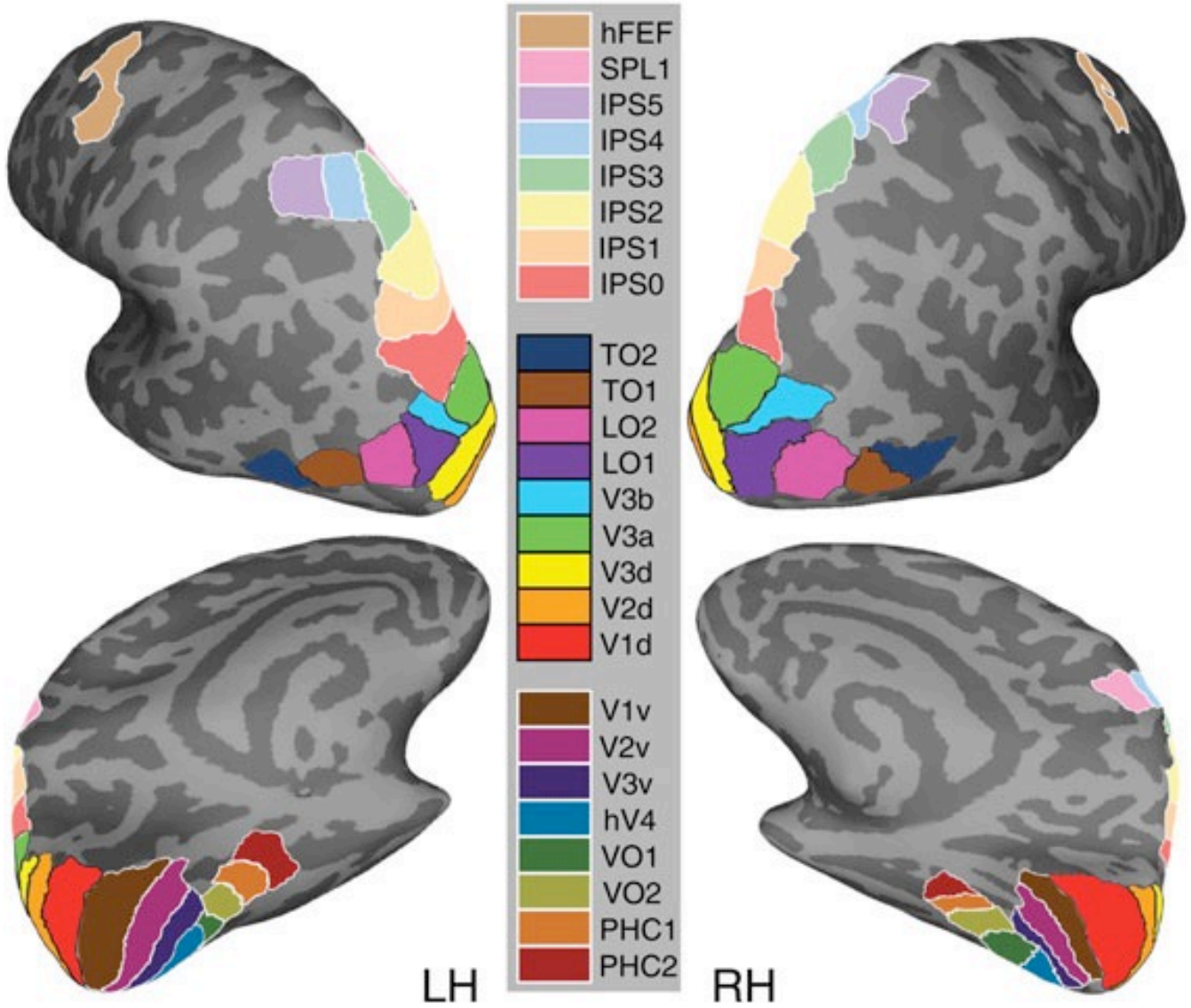
- Organized retinotopically
- V1: orientation selective and contrast & spatial frequency sensitive
- Beyond V1: depth, color, & motion perception

higher-order visual cortex (high-level vision)

- Visually guided actions (dorsal)
- Object recognition (ventral)
- Face recognition (ventral)
- Scene perception (ventral)



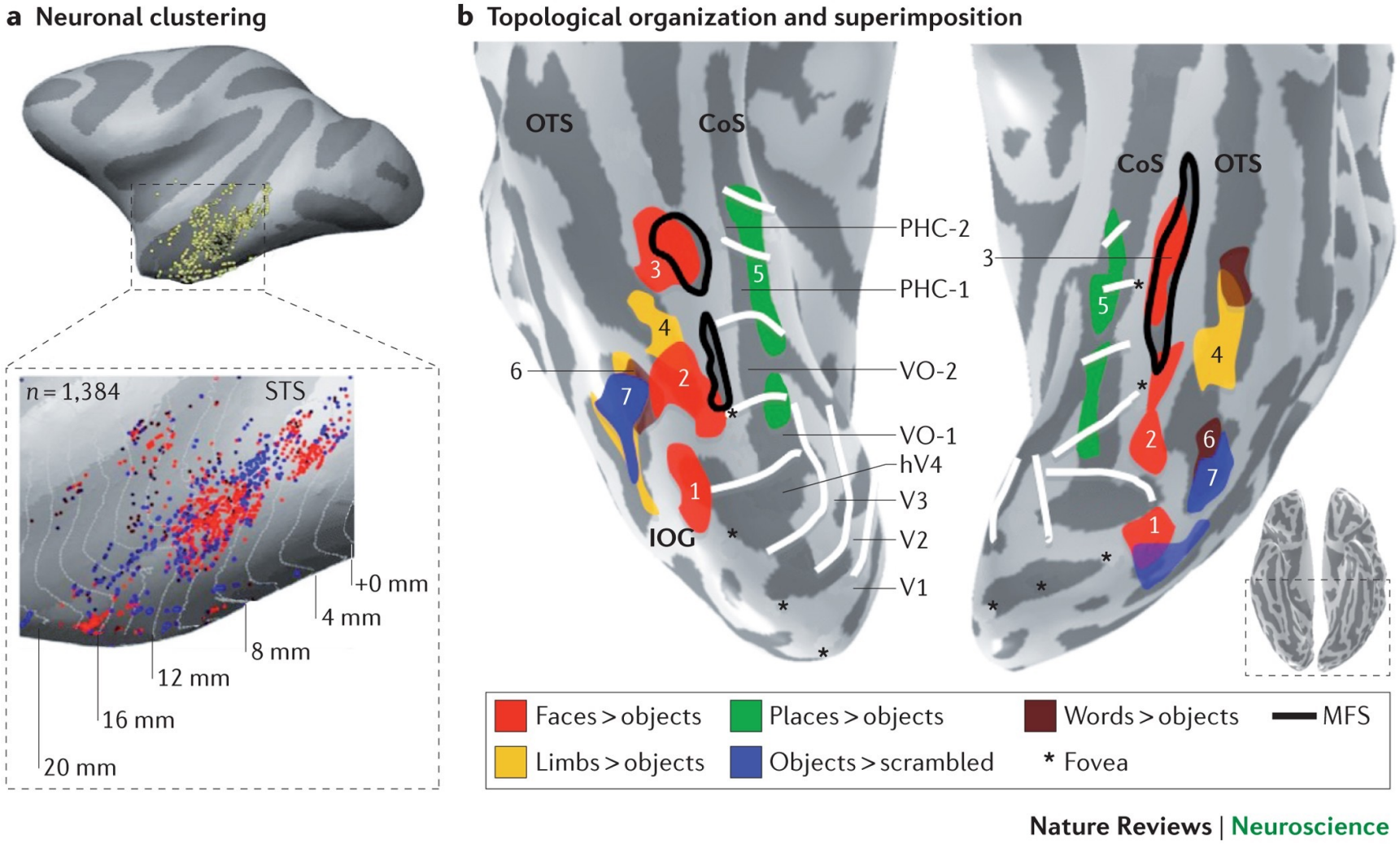
More retinotopic regions



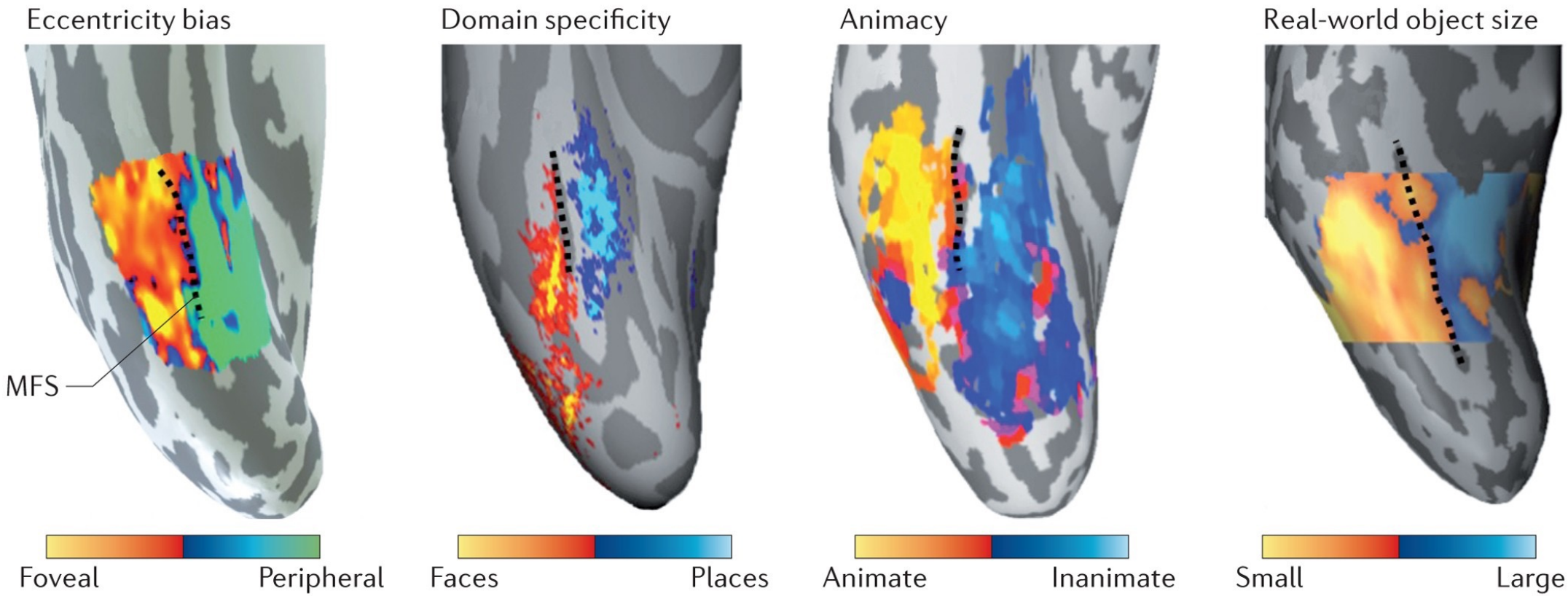
Wang et al., 2015

early visual cortex
(low-level vision)

higher-order visual cortex
(high-level vision)



Grill-Spector & Weiner (2014)


Eccentricity bias
MFS
Foveal
Peripheral
Domain specificity
Faces
Places
Animacy
Animate
Inanimate
Real-world object size
Small
Large

What’s new?

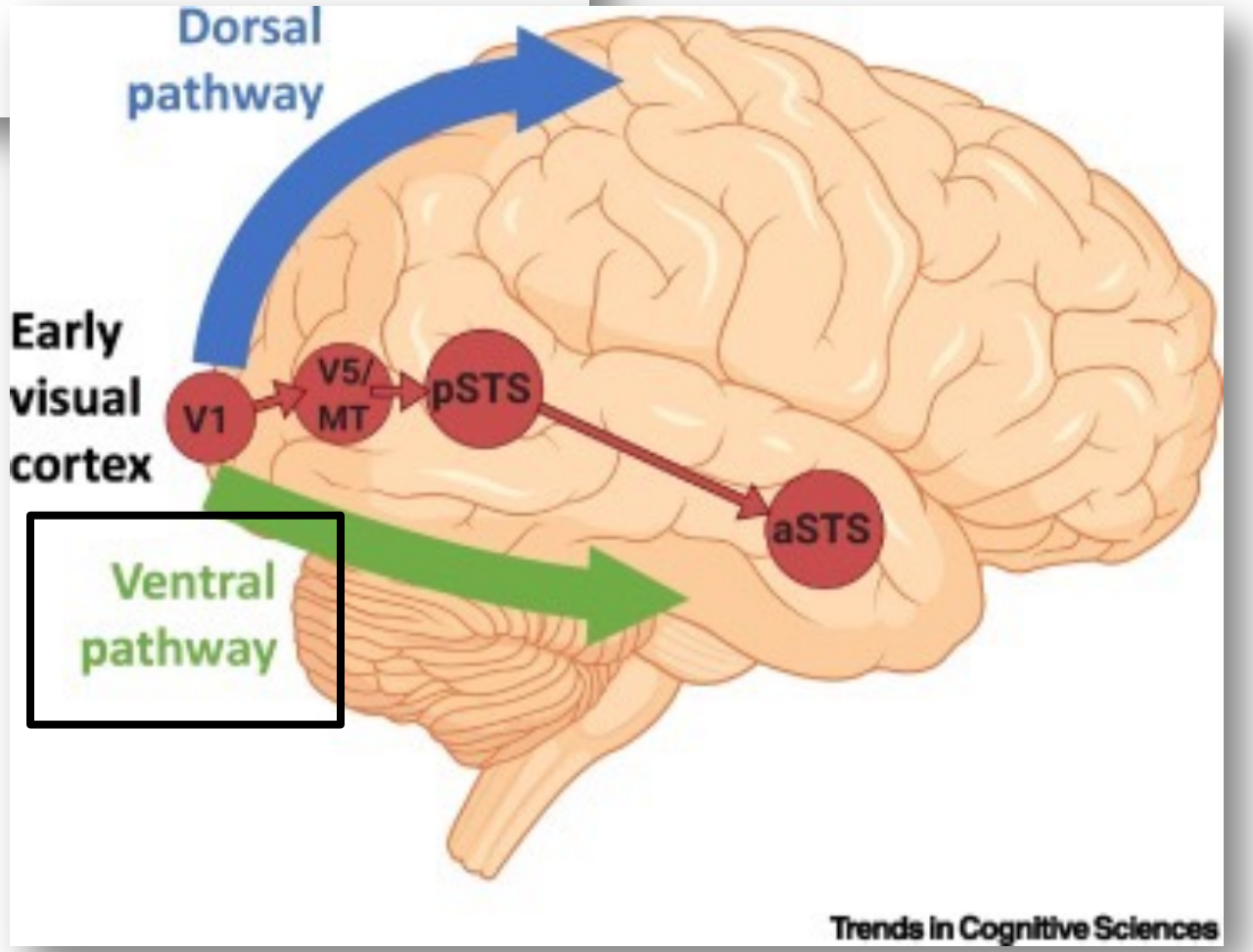
CellPress

Trends in Cognitive Sciences

Opinion

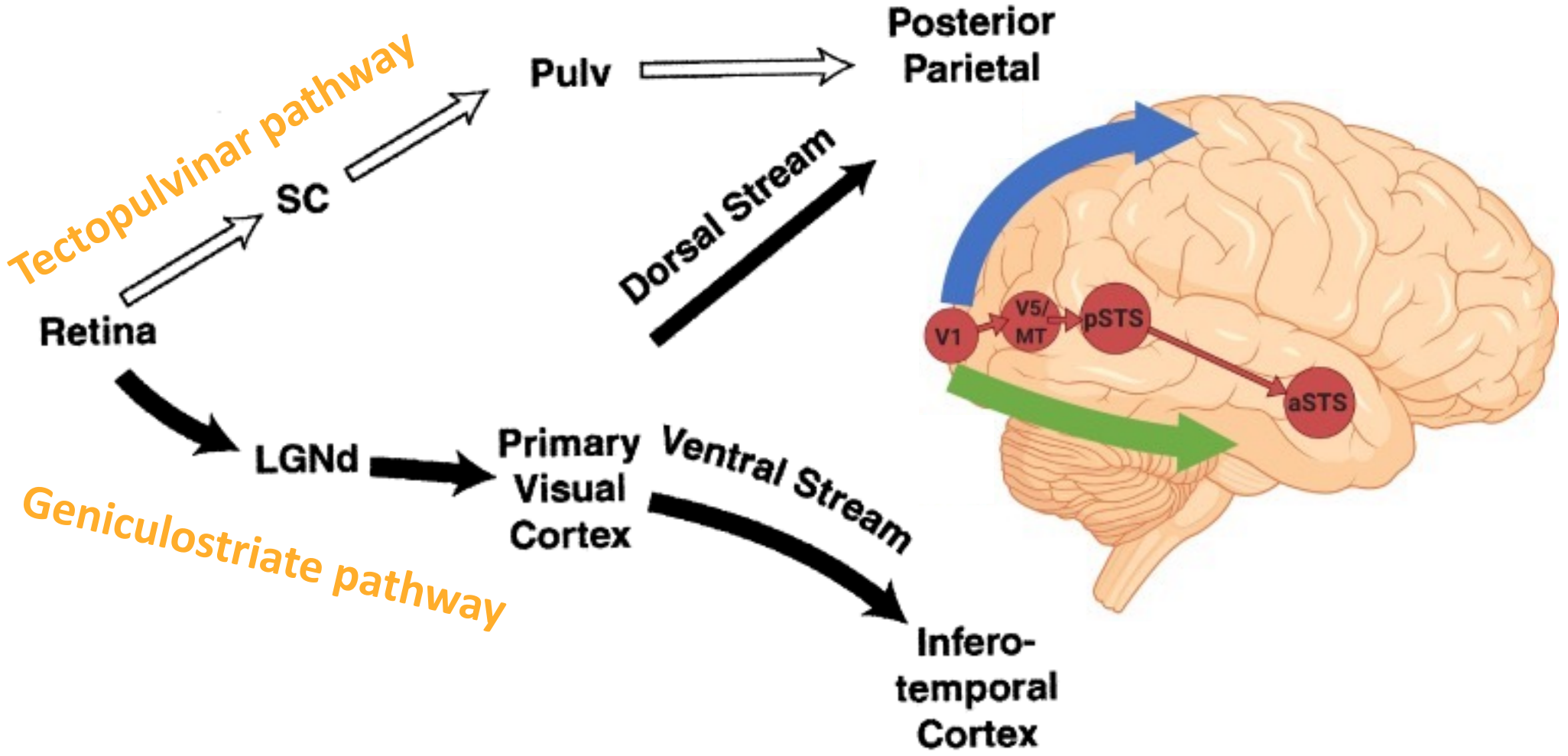
Evidence for a Third Visual Pathway Specialized for Social Perception

David Pitcher[1,*] and Leslie G. Ungerleider[2]



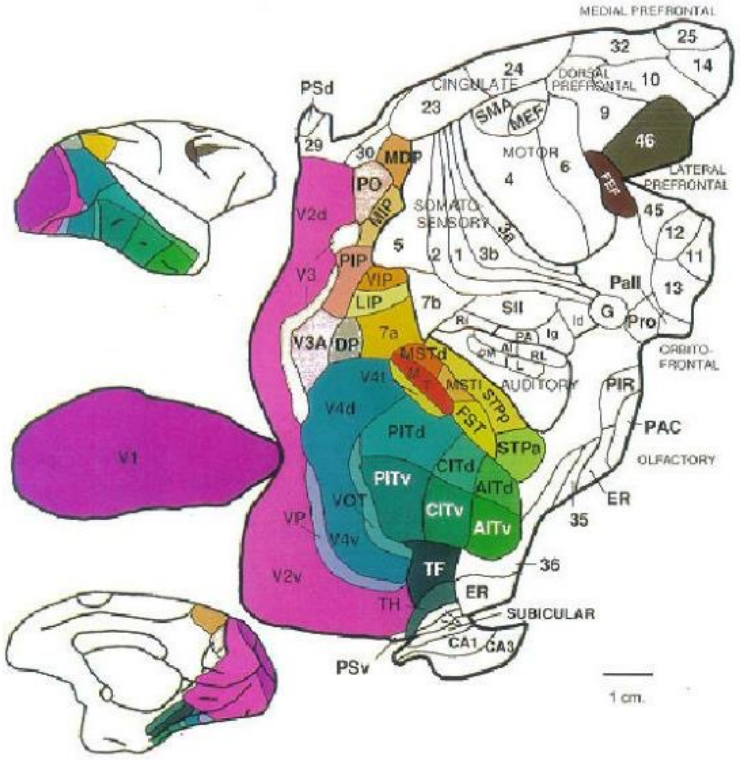
Pitcher & Ungerleider (2021)

Visual Pathways

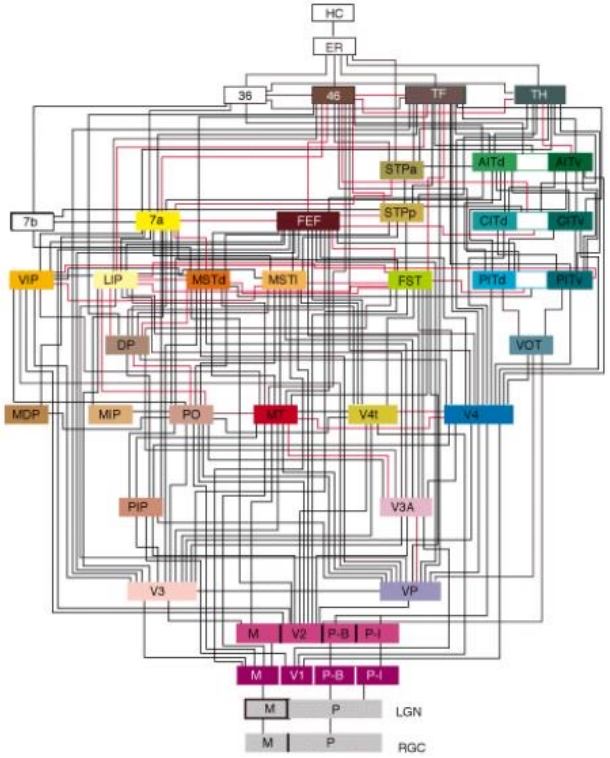


Vision isn't just bottom-up processing

How much of cortex is visual?



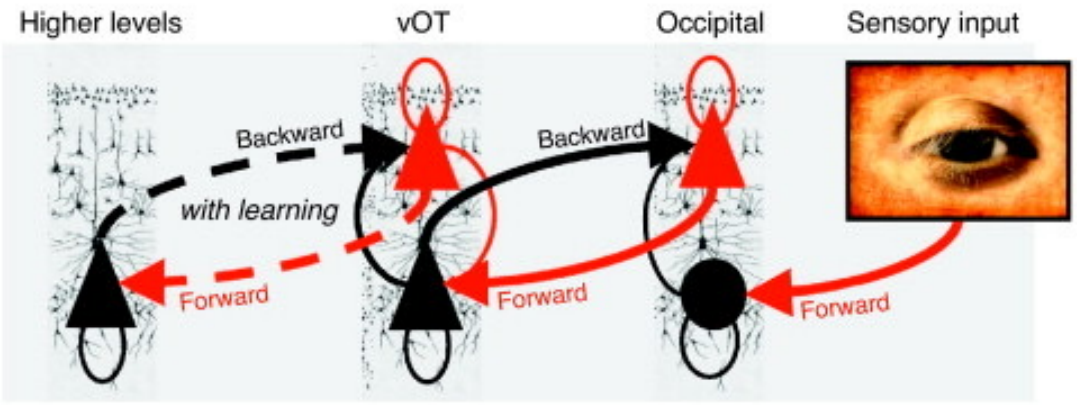
Van Essen flat map of macaque cortex



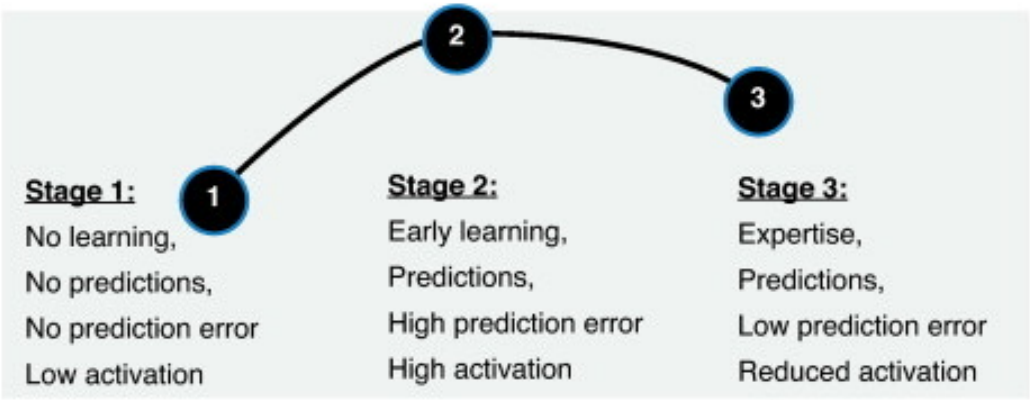
"simplified" Felleman & Van Essen hierarchy

Felleman & Van Essen (1991)

Forward and backward connections to vOT



vOT activation level for 3 stages of learning



Price & Devlin (2011). *TICS*.