# Comparative primate neuroimaging and human brain evolution

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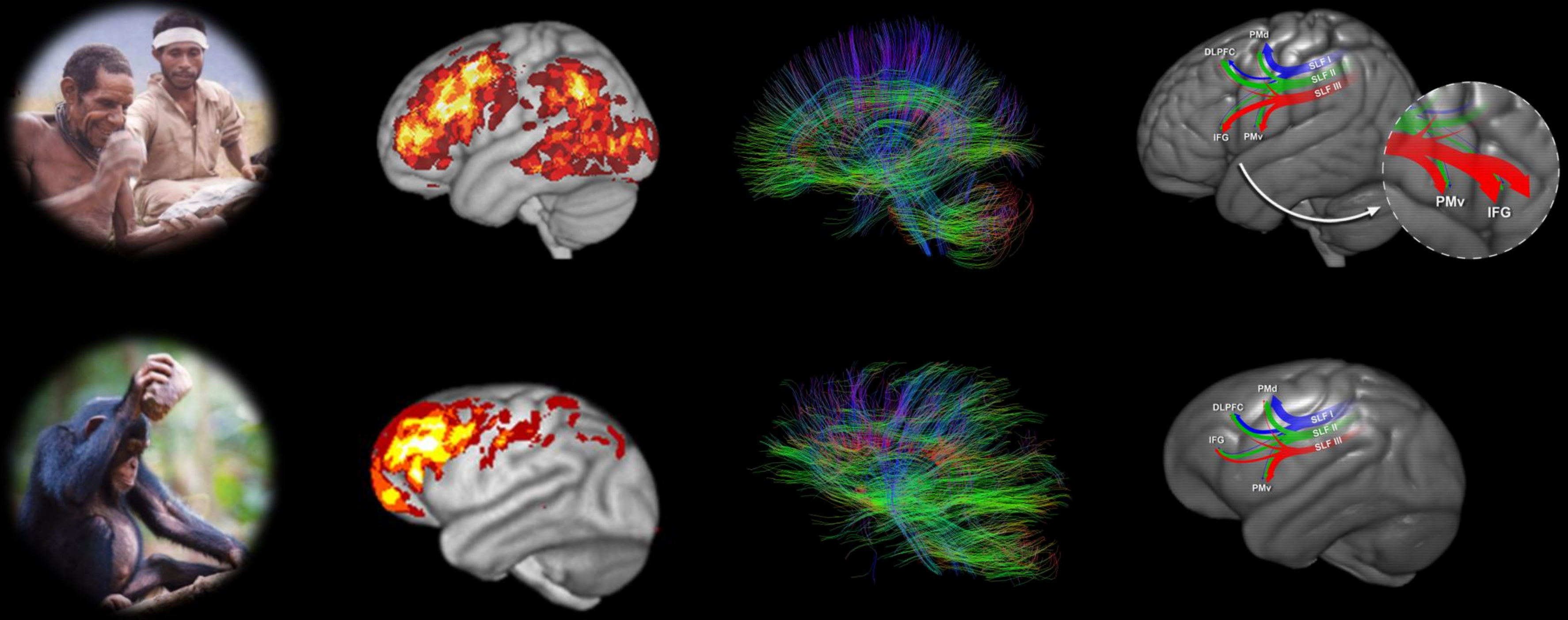

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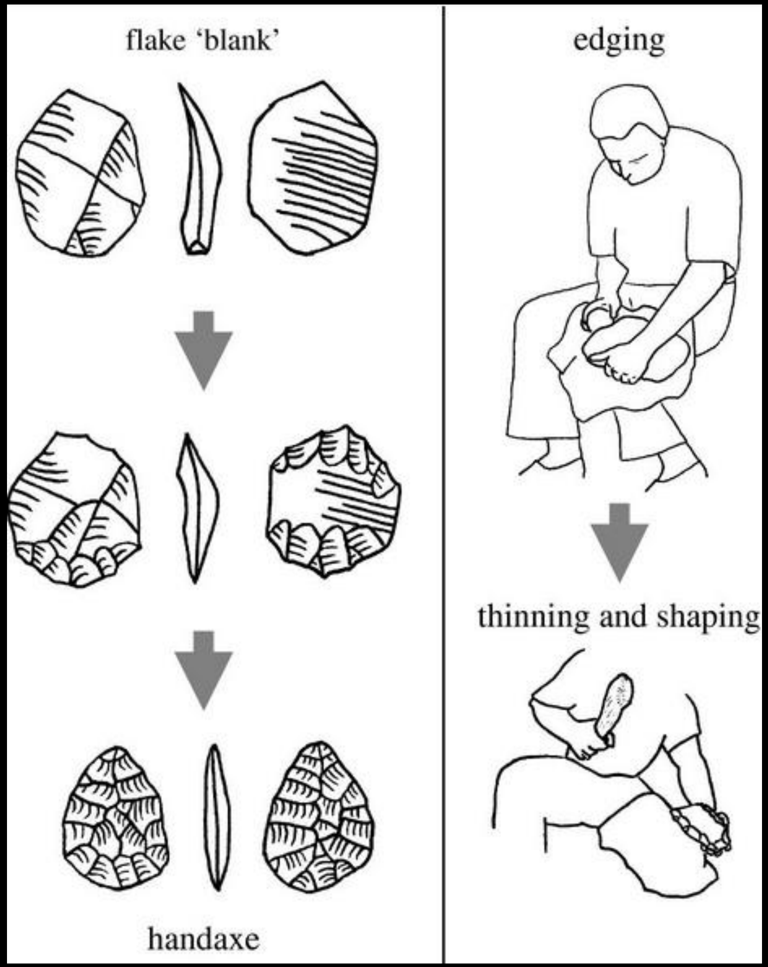
# Why comparative neuroscience?

1. Understand human brains in an evolutionary context
2. Unique aspects of human brains → unique disease manifestations
3. Evolved variation is a source of structure-function information

# How to study how our brains evolved?

1. Comparisons with living primates
2. Plasticity & activity in response to evolutionary challenges

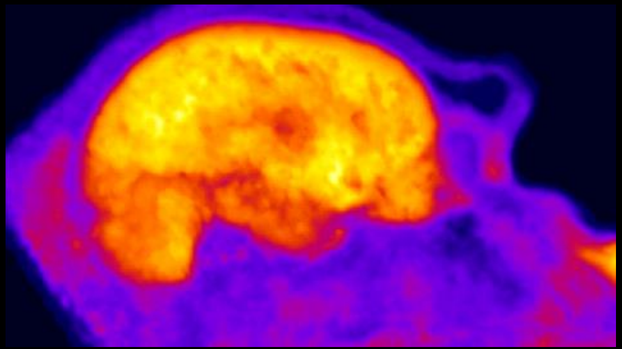
# Primate neural systems for observing others' behavior

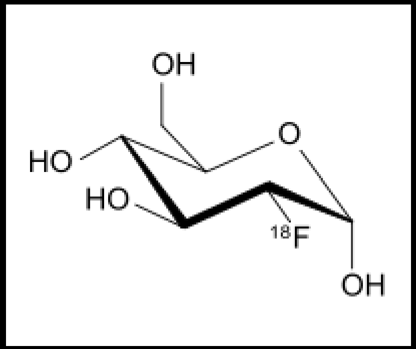




Experimental and field studies indicate that whereas many primate species can copy the <u>result</u> of observed actions (EMULATION), humans are unique in showing a strong bias toward also copying the <u>specific methods</u> (IMITATION)

→ Probably crucial for social transmission of complex, hard-to-learn behaviors

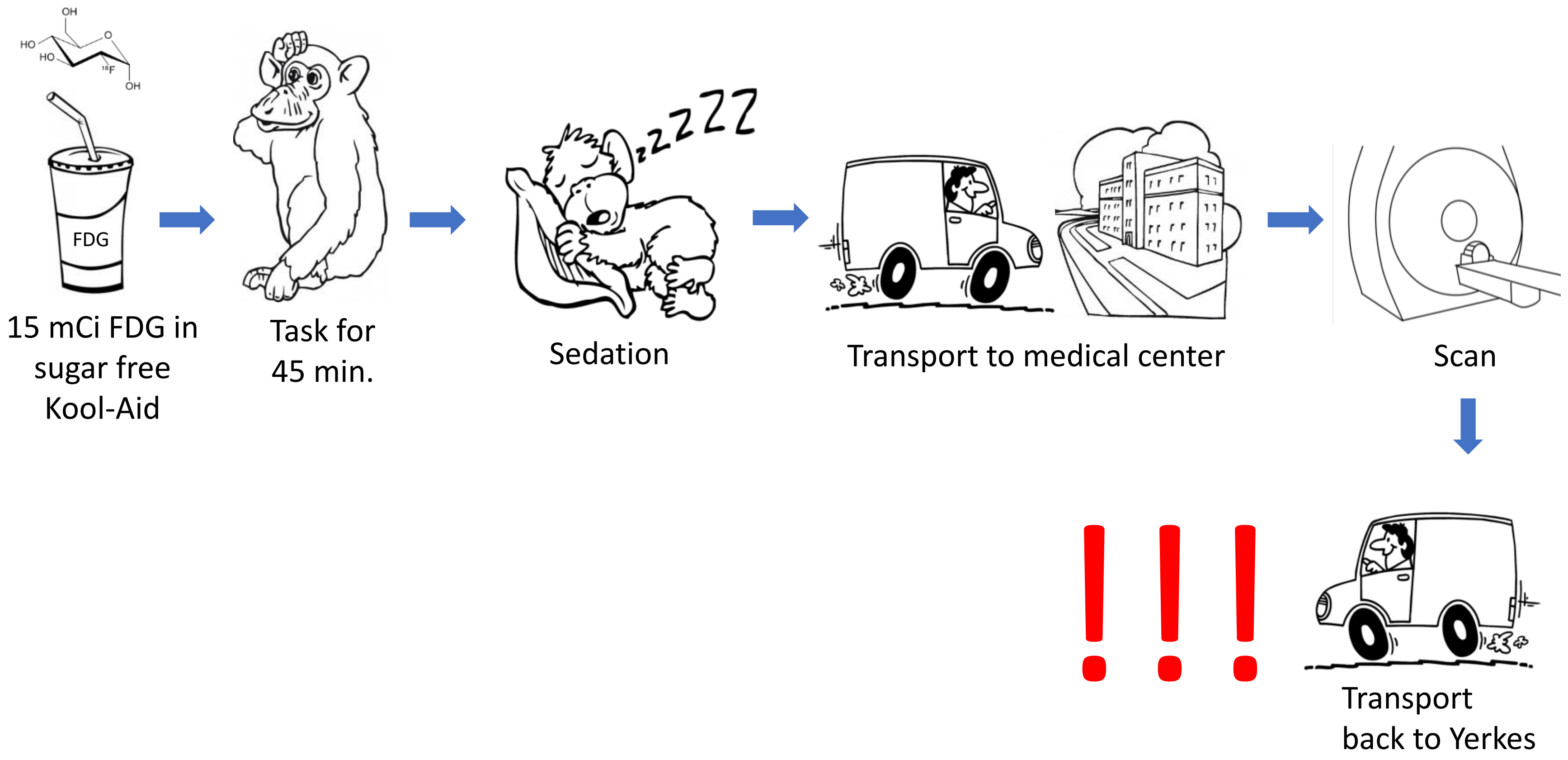
# How does the chimpanzee brain respond to simple observed actions?

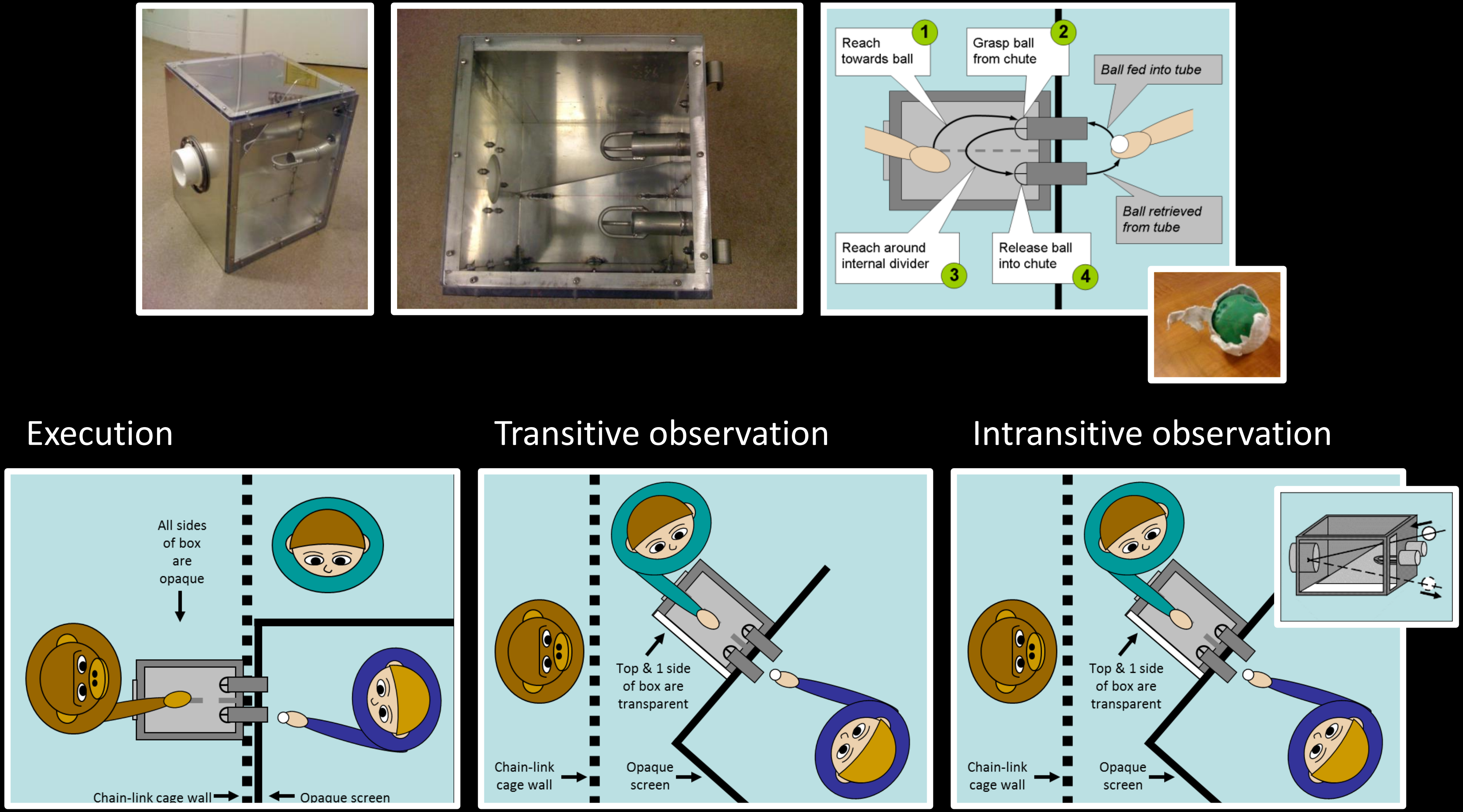





FDG-PET

With Lisa Parr

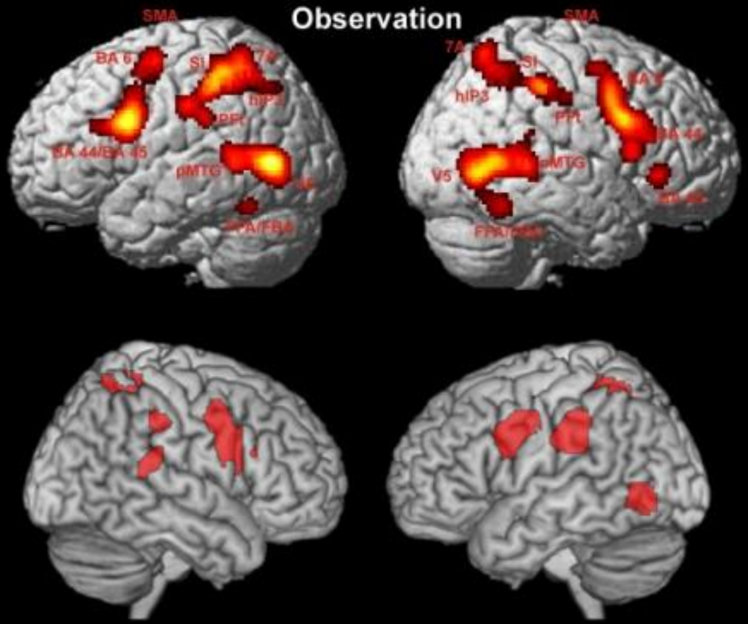

FDG
15 mCi FDG in sugar free Kool-Aid
Task for 45 min.
Sedation
Transport to medical center
Scan
!!!
Transport back to Yerkes

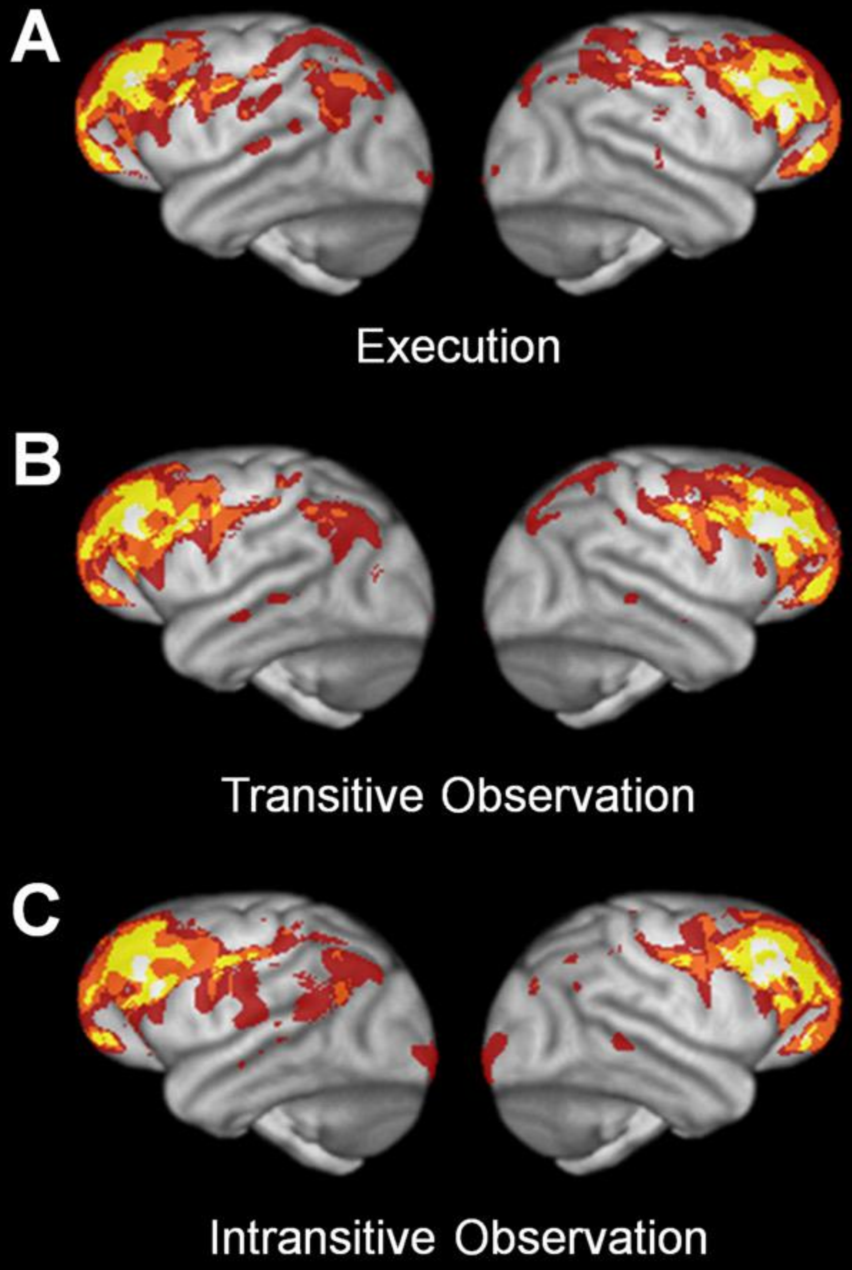


Reach towards ball
1
Grasp ball from chute
2
Ball fed into tube
Ball retrieved from tube
Reach around internal divider
3
Release ball into chute
4
Execution
Transitive observation
Intransitive observation
All sides of box are opaque
Chain-link cage wall
Opaque screen
Top & 1 side of box are transparent
Chain-link cage wall
Opaque screen
Top & 1 side of box are transparent
Chain-link cage wall
Opaque screen

For all of these conditions, chimp activation was overwhelmingly frontally-focused. This differs from human fMRI studies.

Metanalyses of 100+ human fMRI studies[1,2]

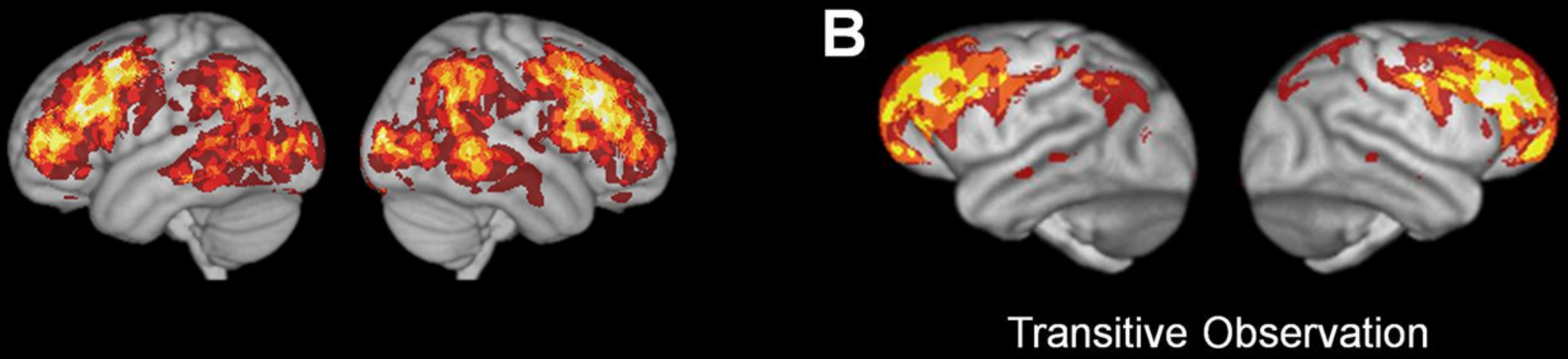



*[1] Molenberghs et al (2012). Neurosci Biobehav Rev 36(1):341-349.*
*[2] Caspers et al (2010). Neuroimage 50(3):1148-1167.*

*Hecht et al (2013). J Neurosci (35):14117-34*

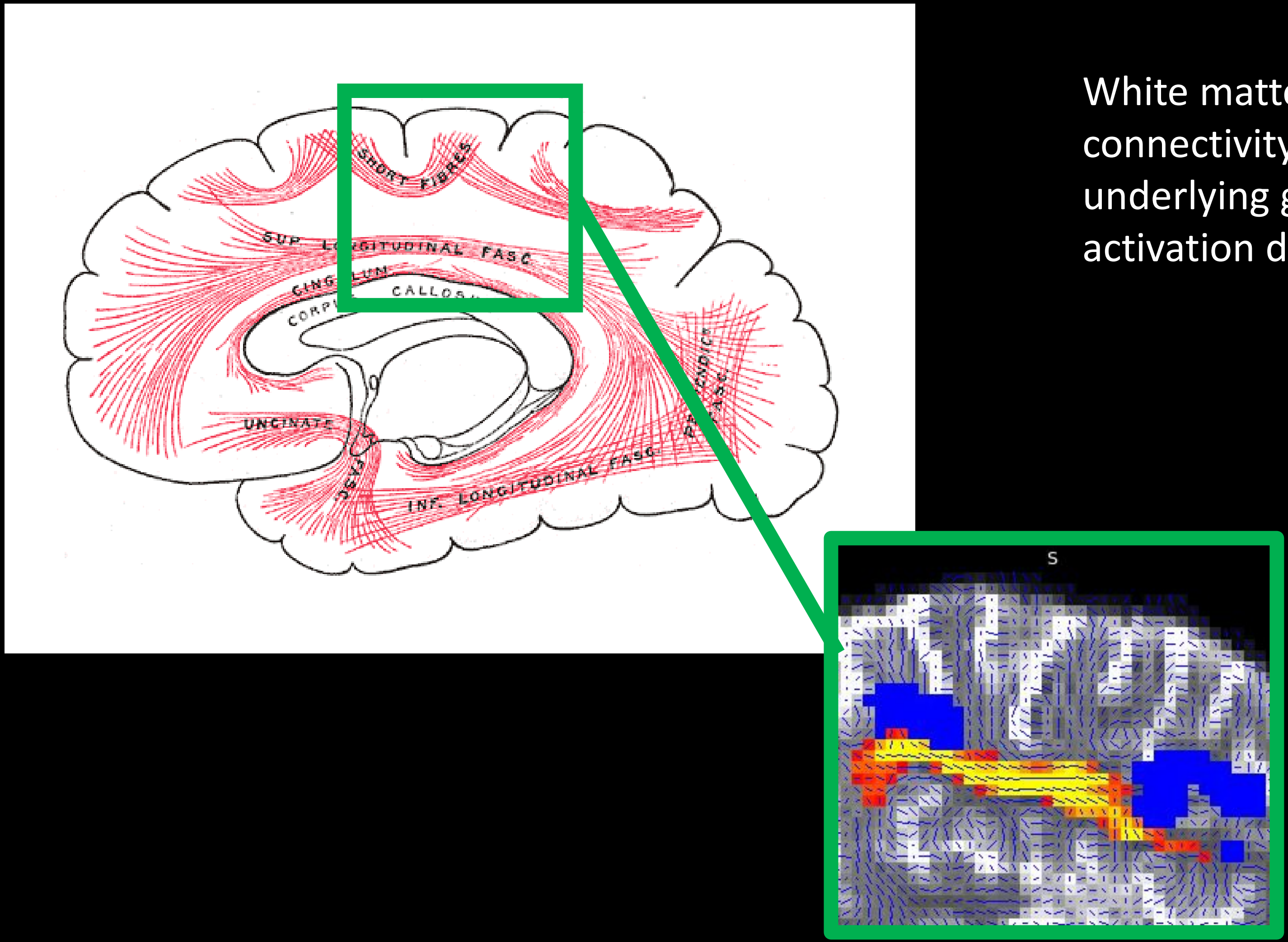
# Direct FDG-PET comparison with humans




More bottom-up perceptual activation in humans
Chimp activation largely focused in DLPFC

*Hecht et al (2013). J Neurosci (35):14117-34*

# Diffusion tensor imaging (DTI)

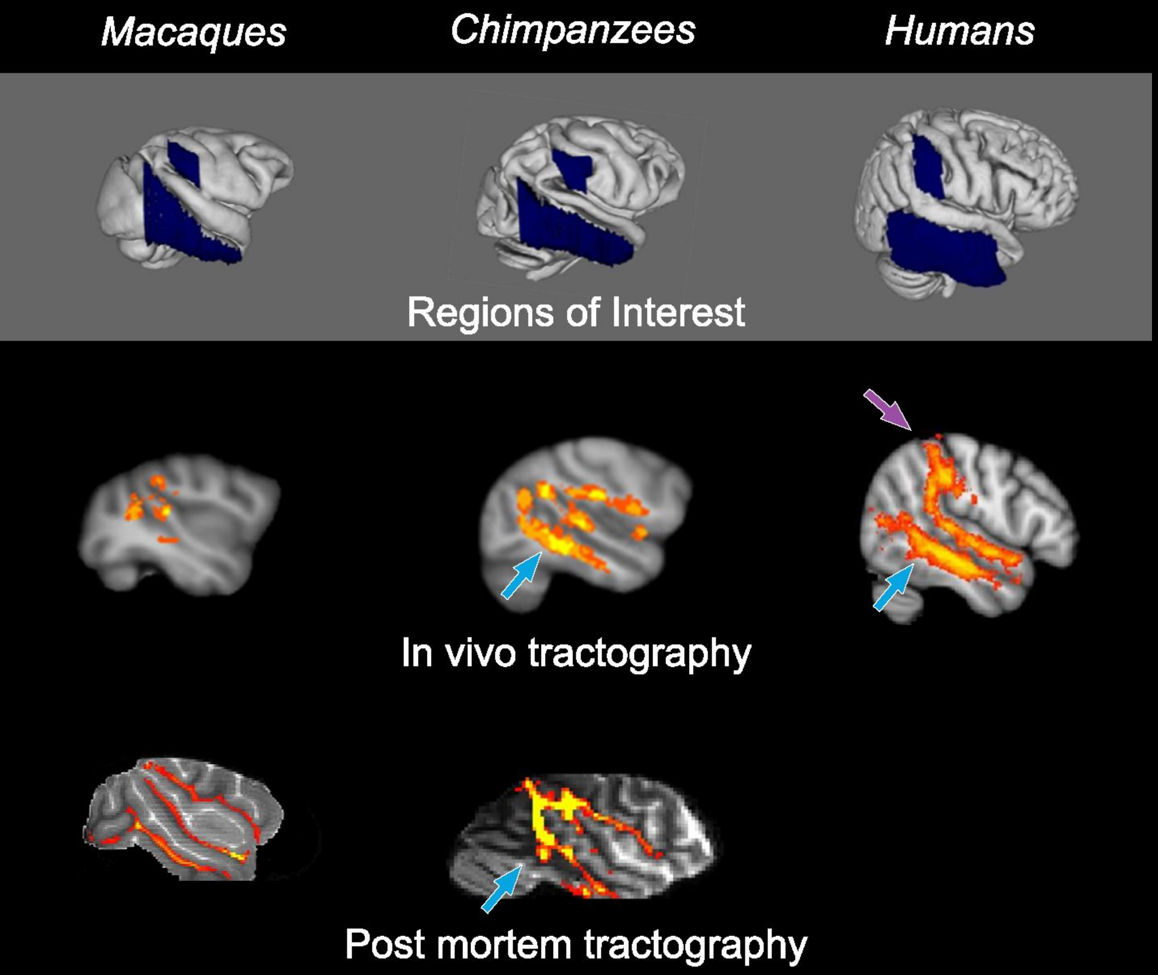


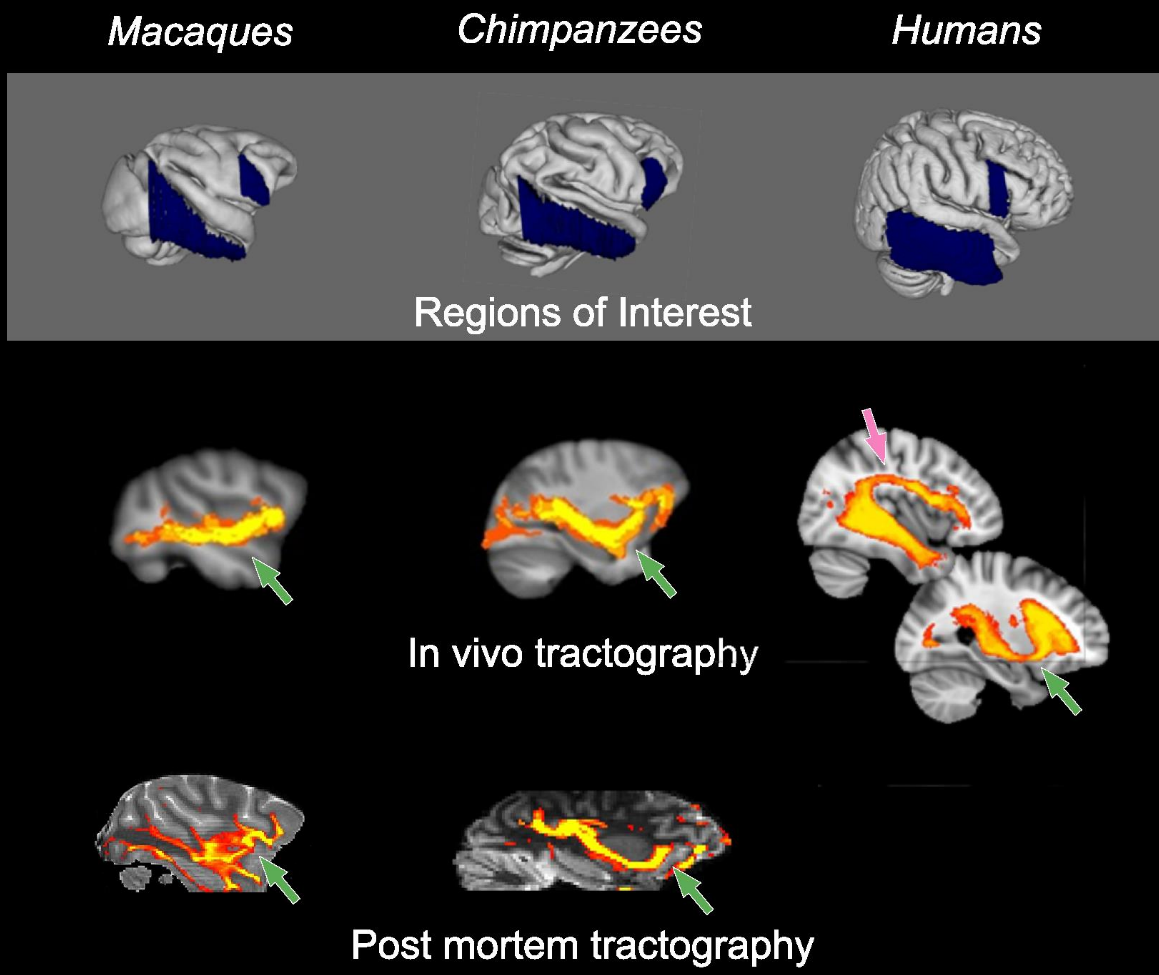

White matter connectivity differences underlying gray matter activation differences?

With Todd Preuss

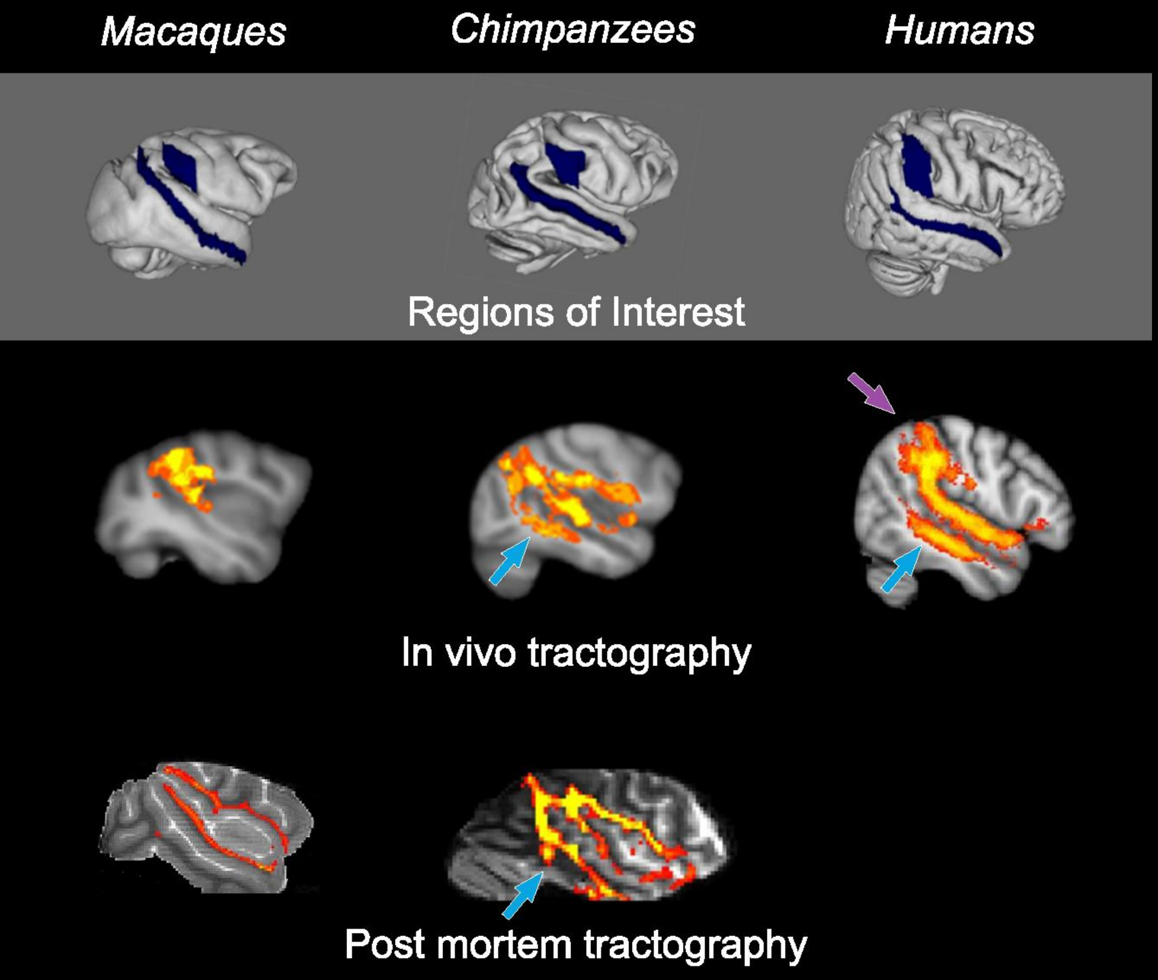
# Connections with object-sensitive inferotemporal cortex

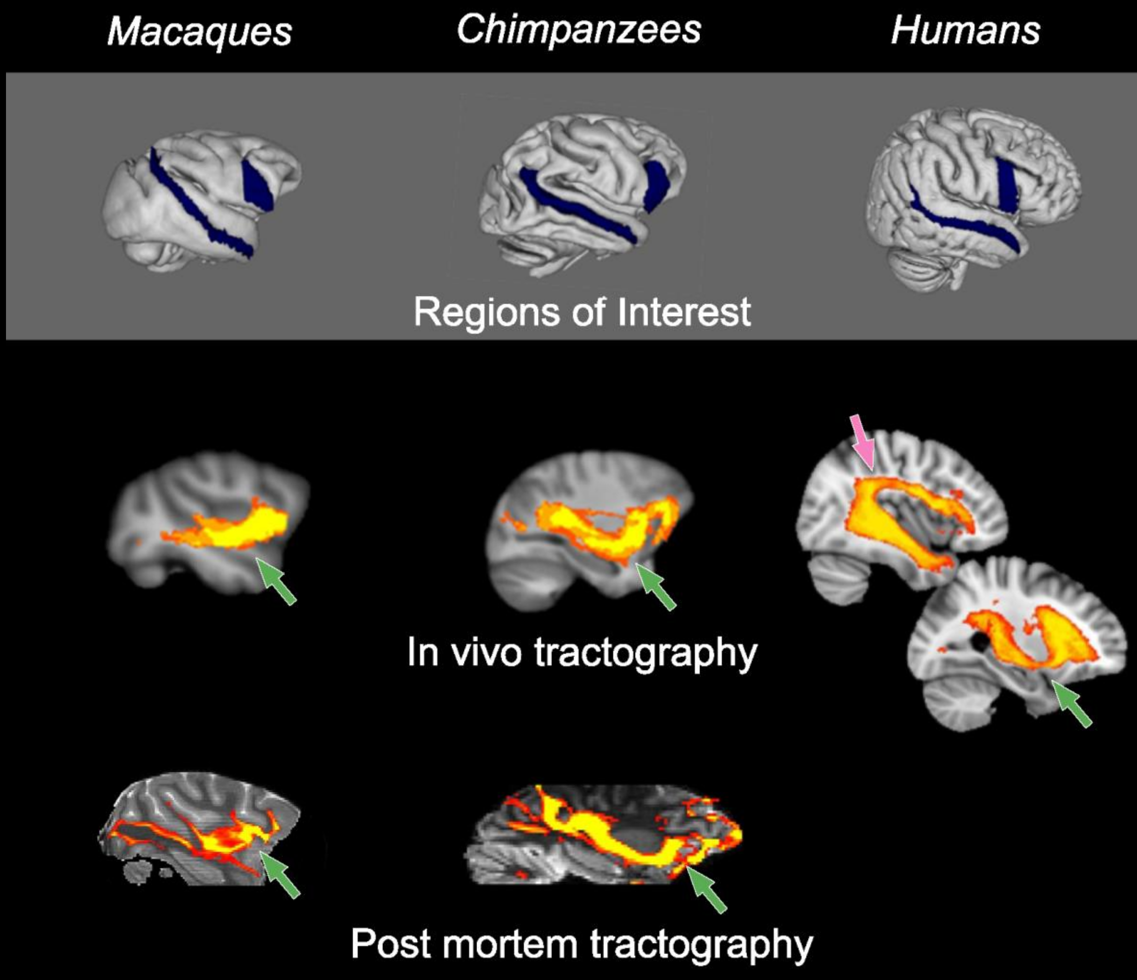
*Regions that were more sensitive to observed action in humans also show stronger white matter connectivity.*



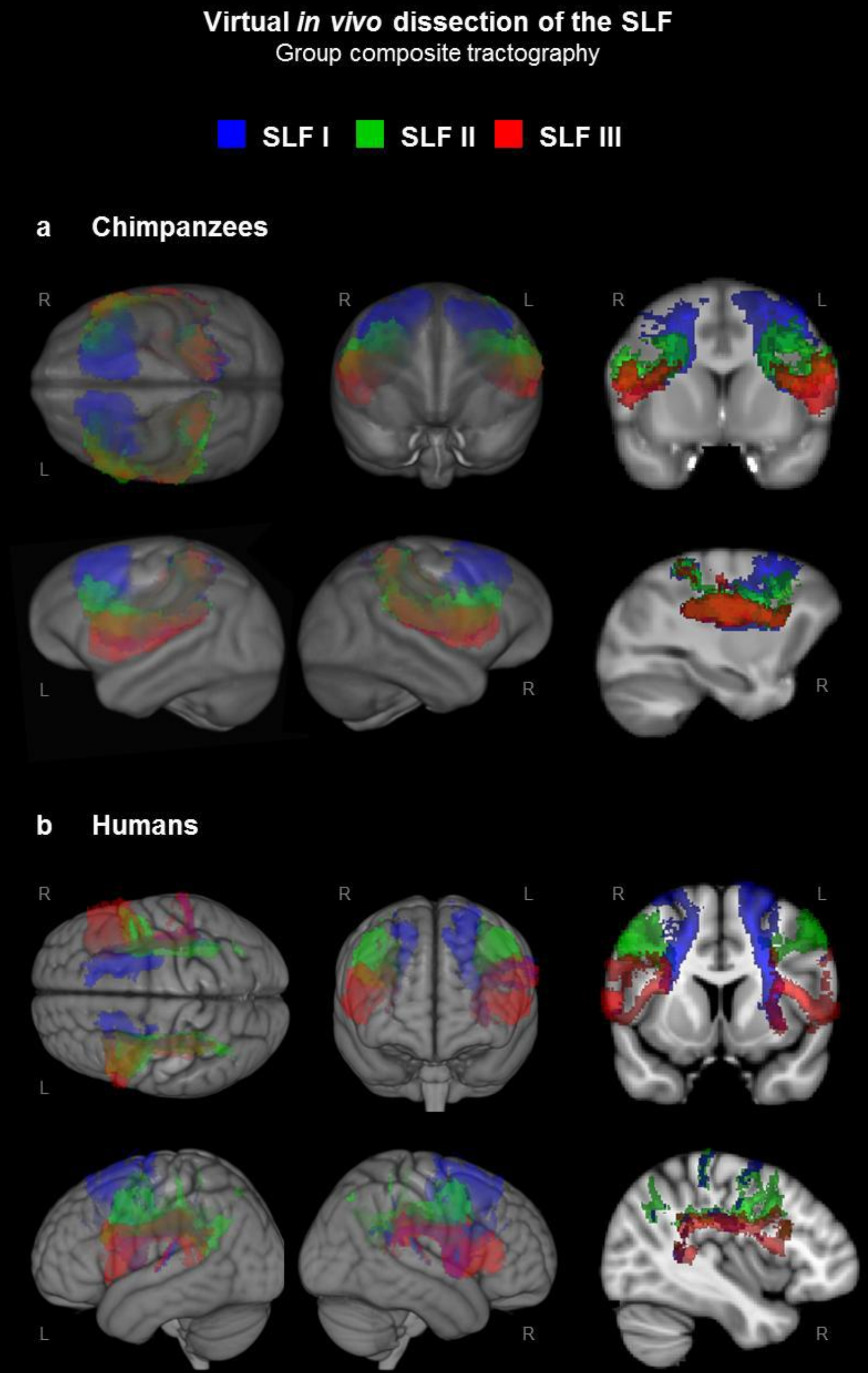



# The “core” action-perception circuit



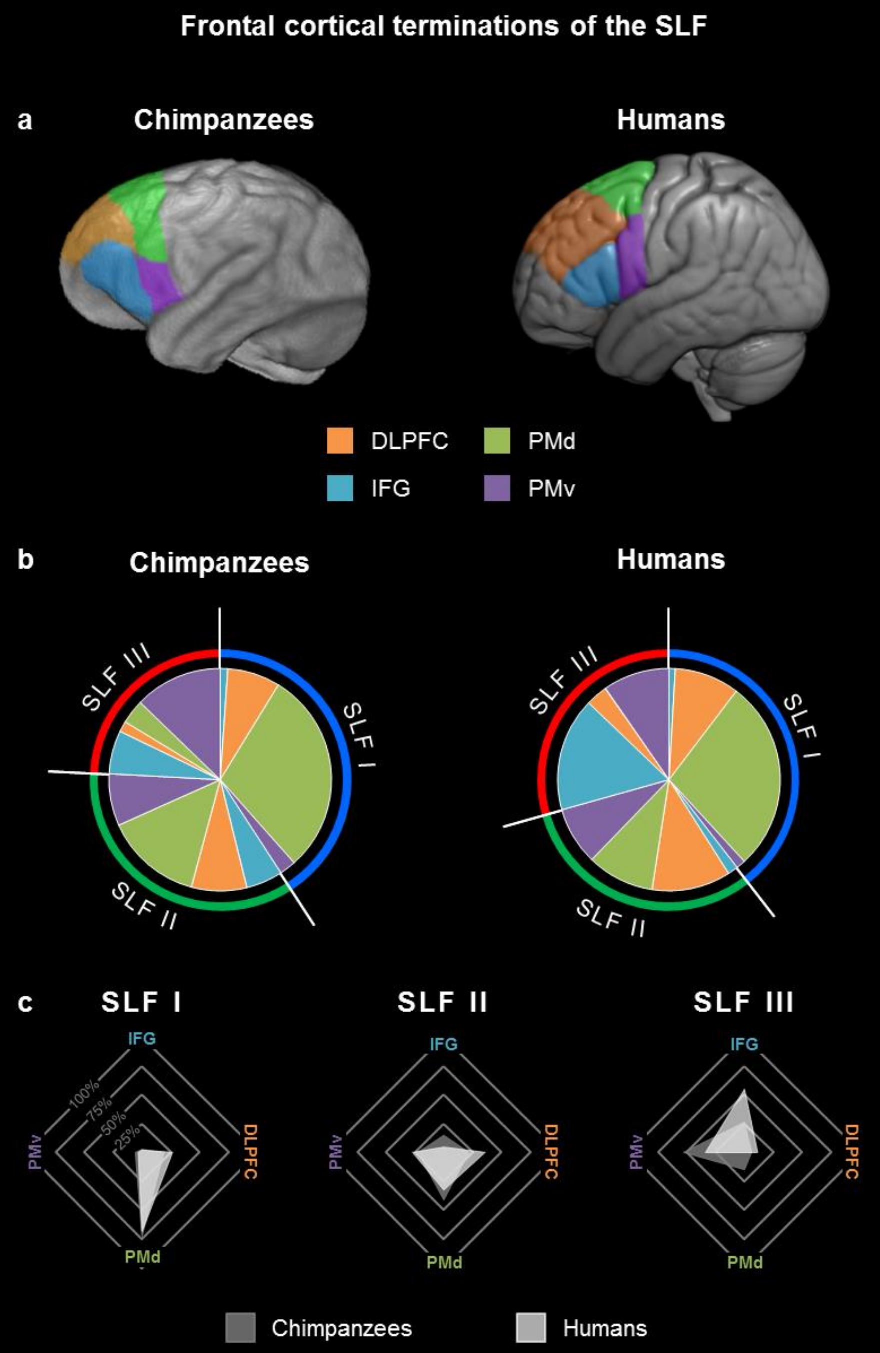
# Virtual *in vivo* dissection of the superior longitudinal fasciculus

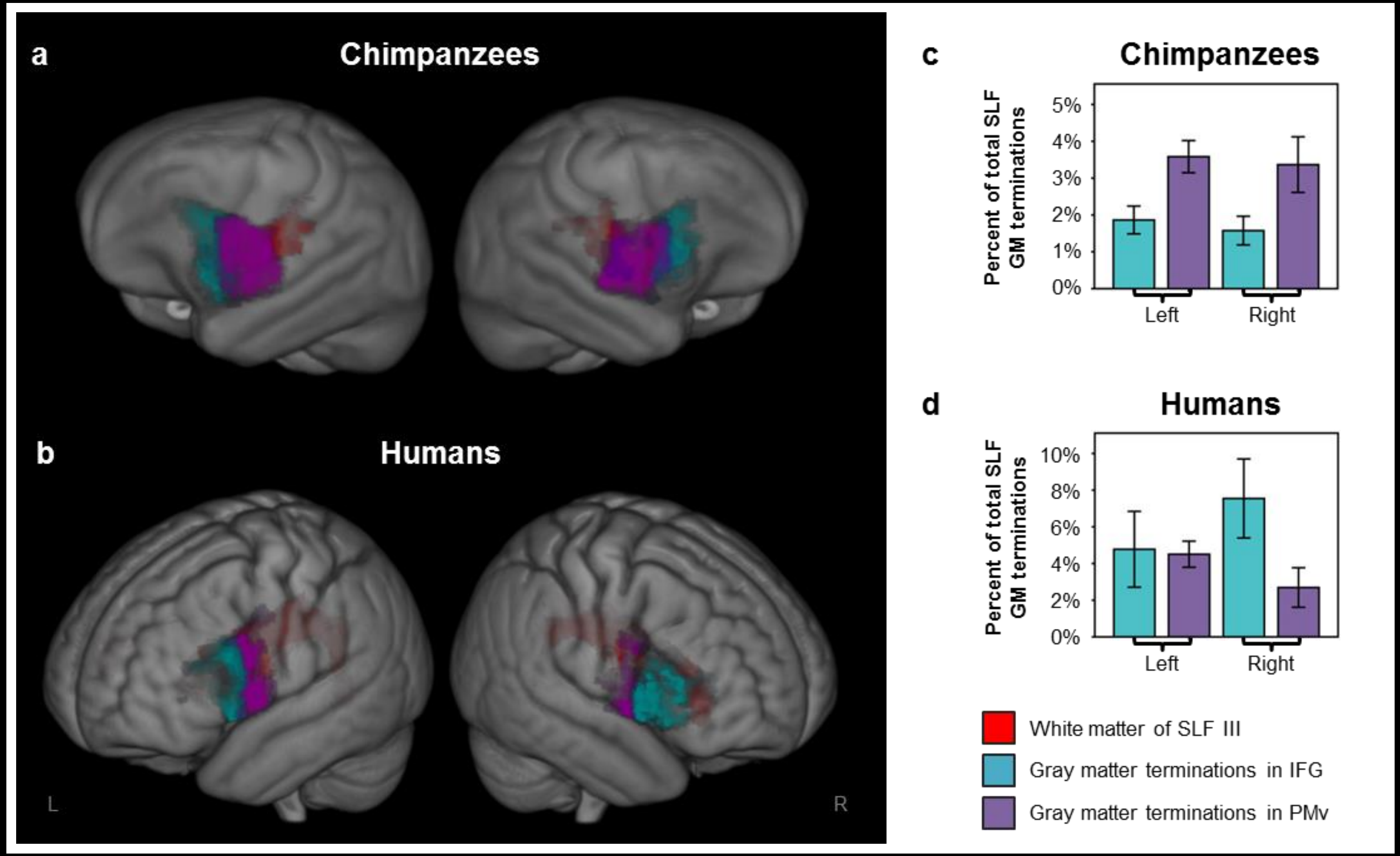



Many aspects of connectivity were similar, except…

Hecht et al. (2015). Neuroimage 108:124-37

# Extension of SLFIII into anterior IFG in the human right hemisphere



## Inferior frontal cortex:

Higher-order action representation

- Complex, hierarchically-structured actions[1]
- Higher-order action planning[2]

[1] Koechlin E, Jubault T. Neuron. 2006 Jun 15;50(6):963-74.
[2] Badre & D'Esposito (2009) Nat Rev Neurosci 10, 659-669

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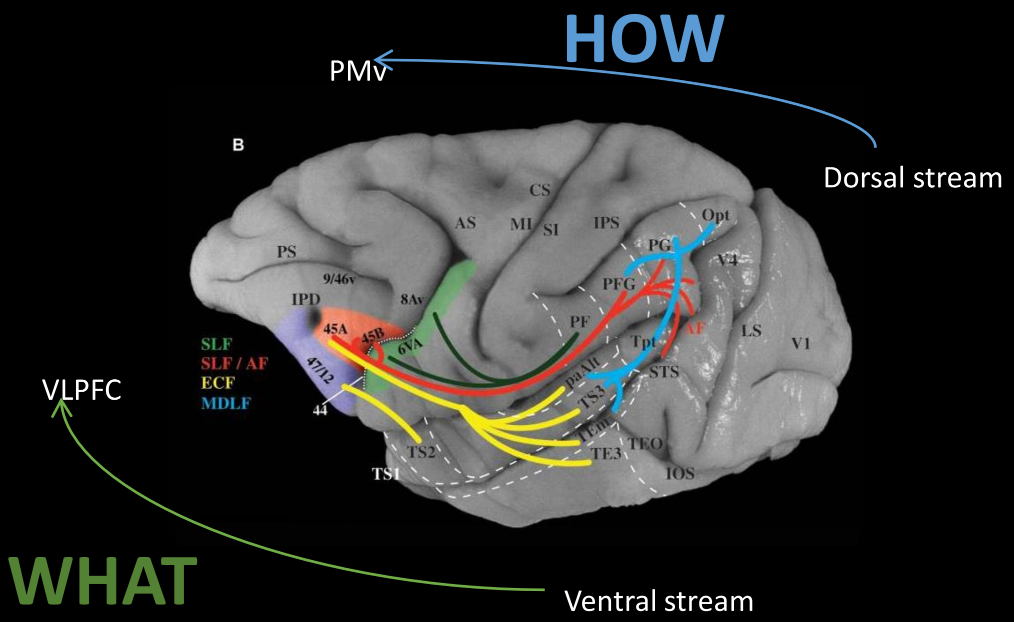
*Increased integration between cognitive control & detailed visuo-motor processing*

## Inferior parietal cortex:

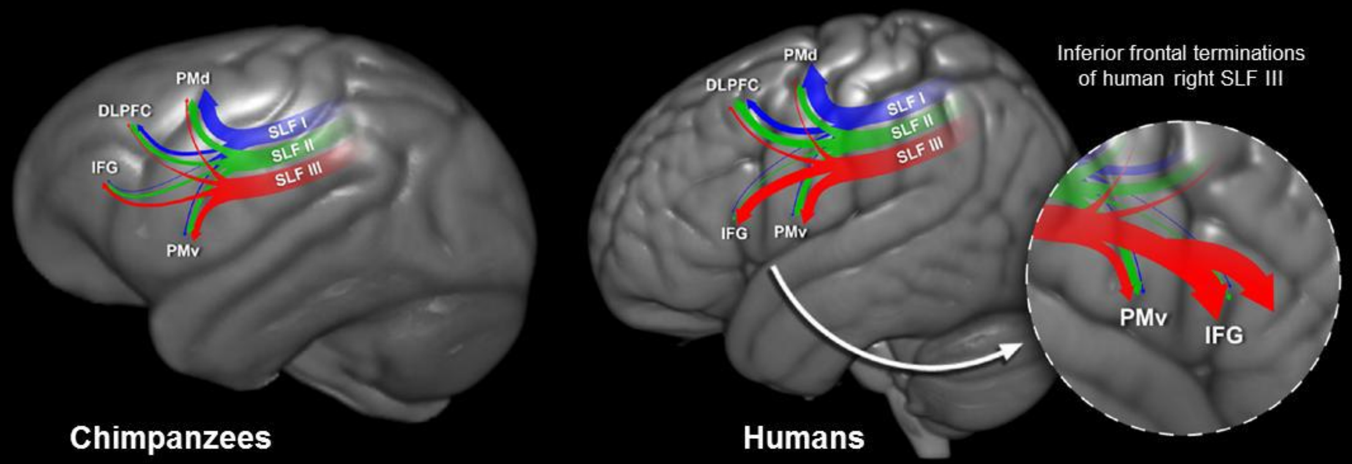
Details of movements in space and time

- Relationships between body parts and objects in space[3]
- Proprioceptive feedback related to motor movements and object manipulation[4]

[3] Rizzolatti et al (1997) Curr Op Neurobiol 7, 562-567
[4] Rozzzi et al (2008) Eur J Neurosci 8, 1569-88




Petrides & Pandya (2009) PLoS Biology 7(8):e1000170
Mishkin & Ungerleider (1982) Behav Brain Res. 6 (1): 57–77



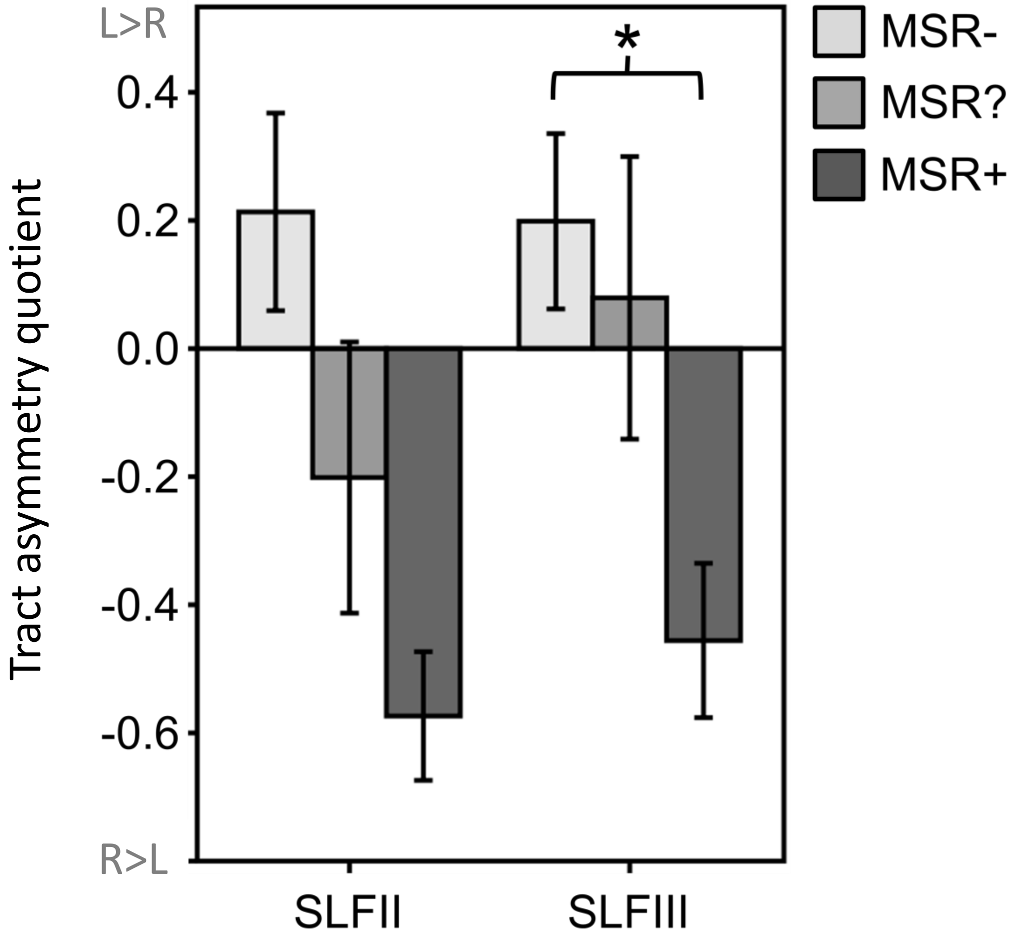

Hecht et al. (2015). Neuroimage 108:124-37

# Another skill that requires top-down/bottom up visuomotor integration: mirror self-recognition

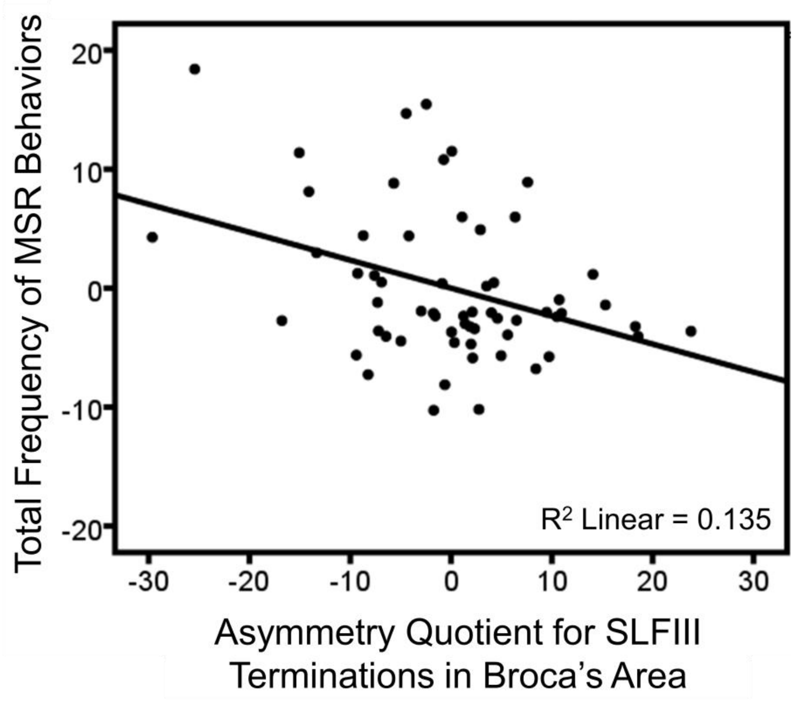
With Bill Hopkins

# Neural predictors of self-recognition in chimpanzees

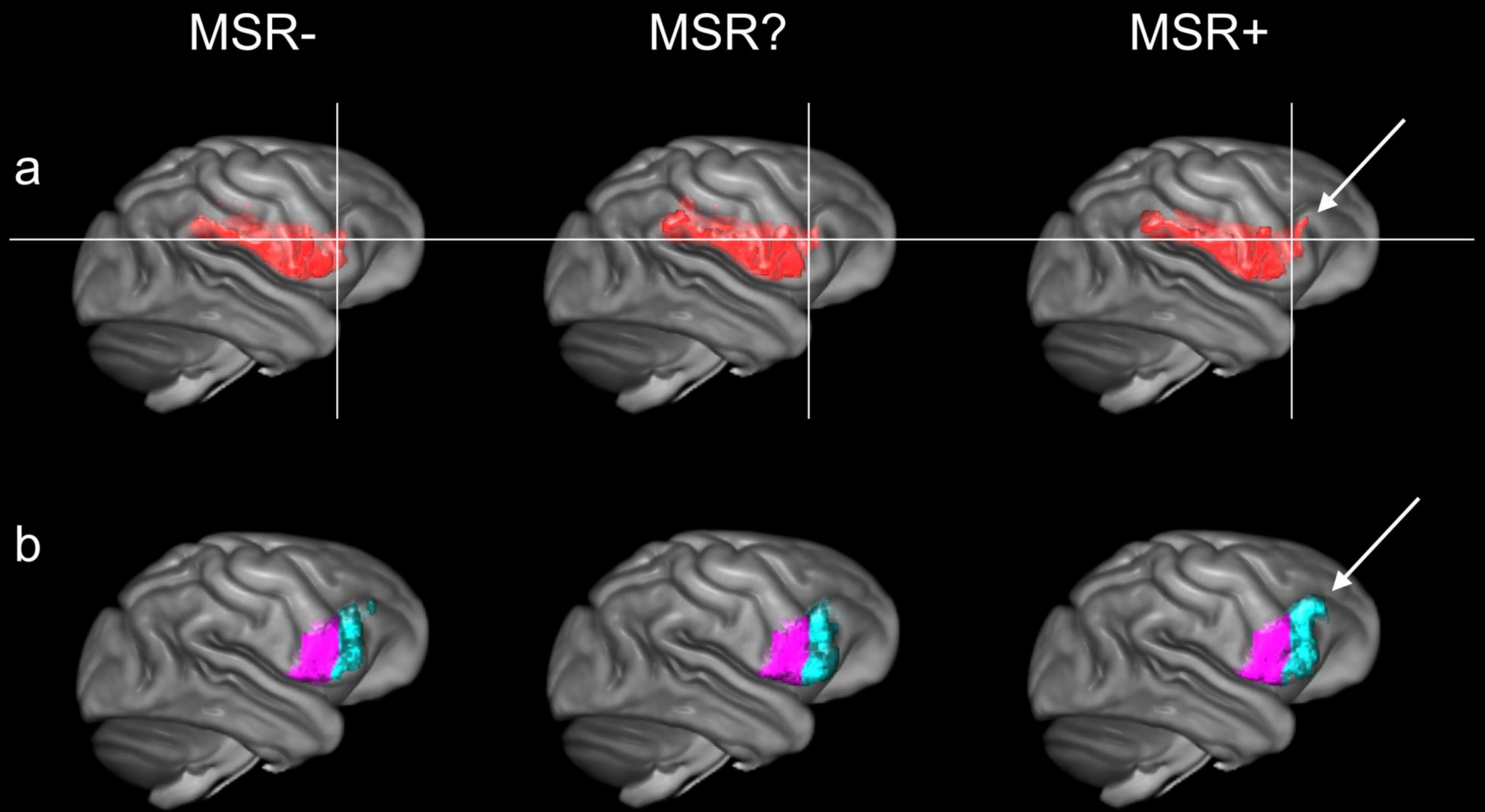
**Right-lateralization of SLFIII white matter tract core**



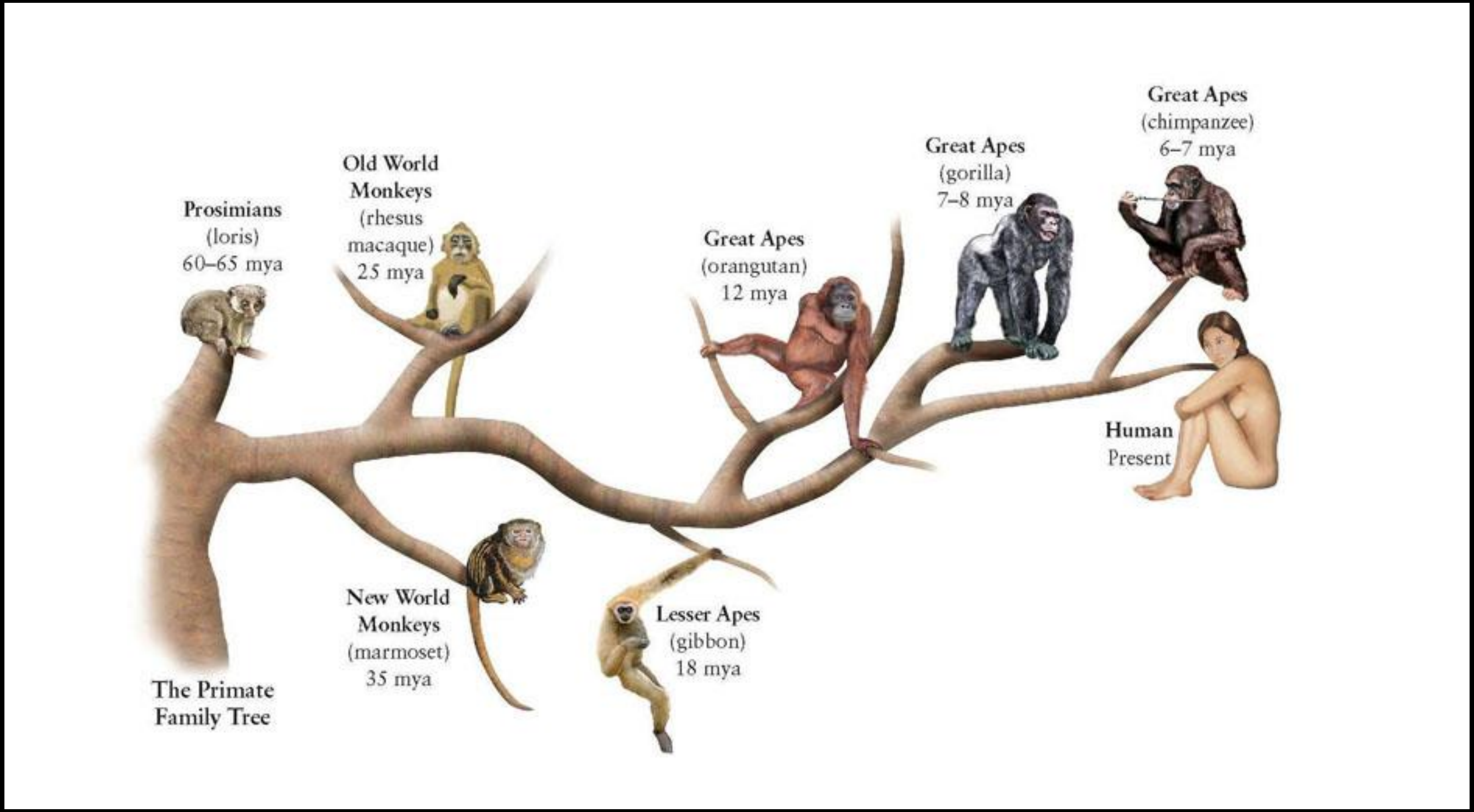

**Rightward asymmetry of SLFIII's gray matter terminations in Broca's area**



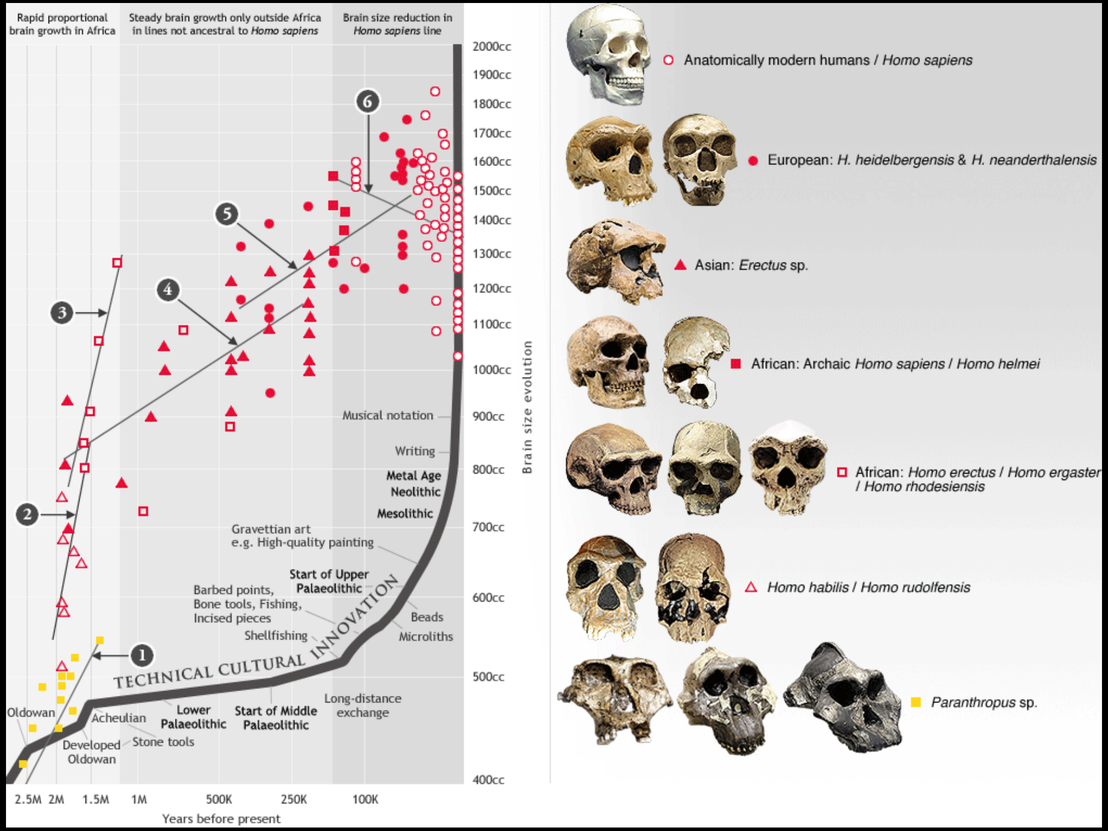
# Visible prefrontal extension of SLFIII in chimps who recognize their own reflection



# But complex technological culture emerged <u>after</u> our divergence from chimps…



# Neural adaptations for tool use likely emerged during the Paleolithic

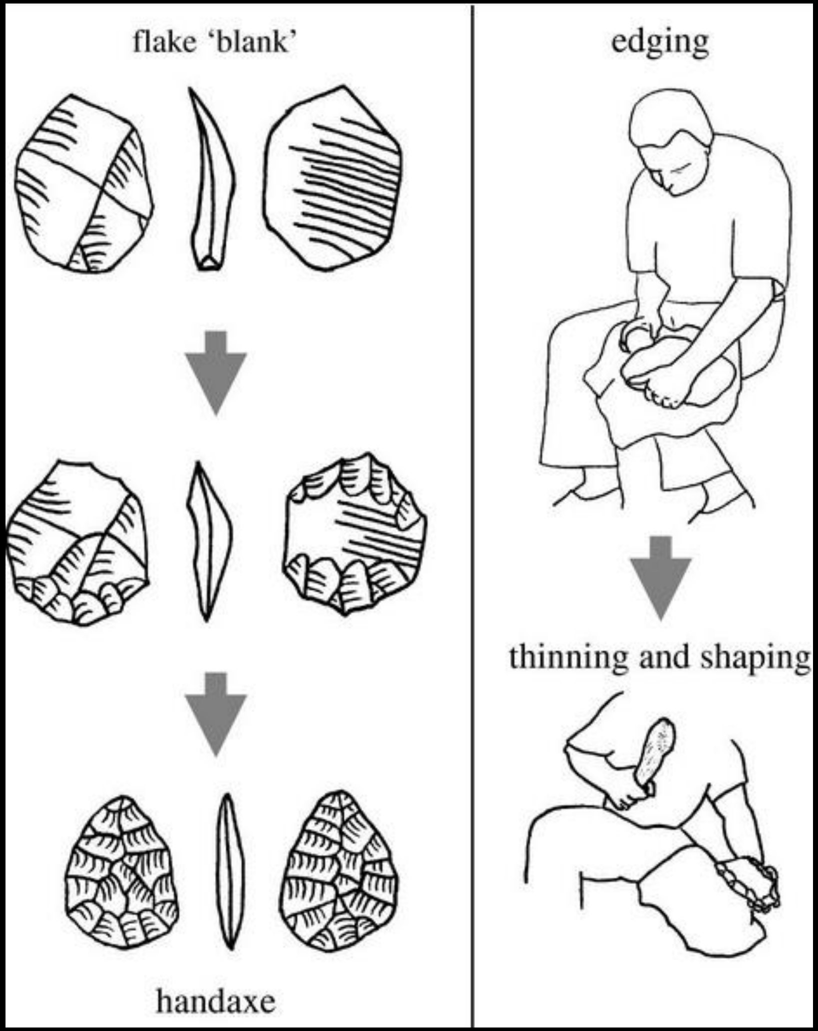



Unfortunately, brains don’t fossilize

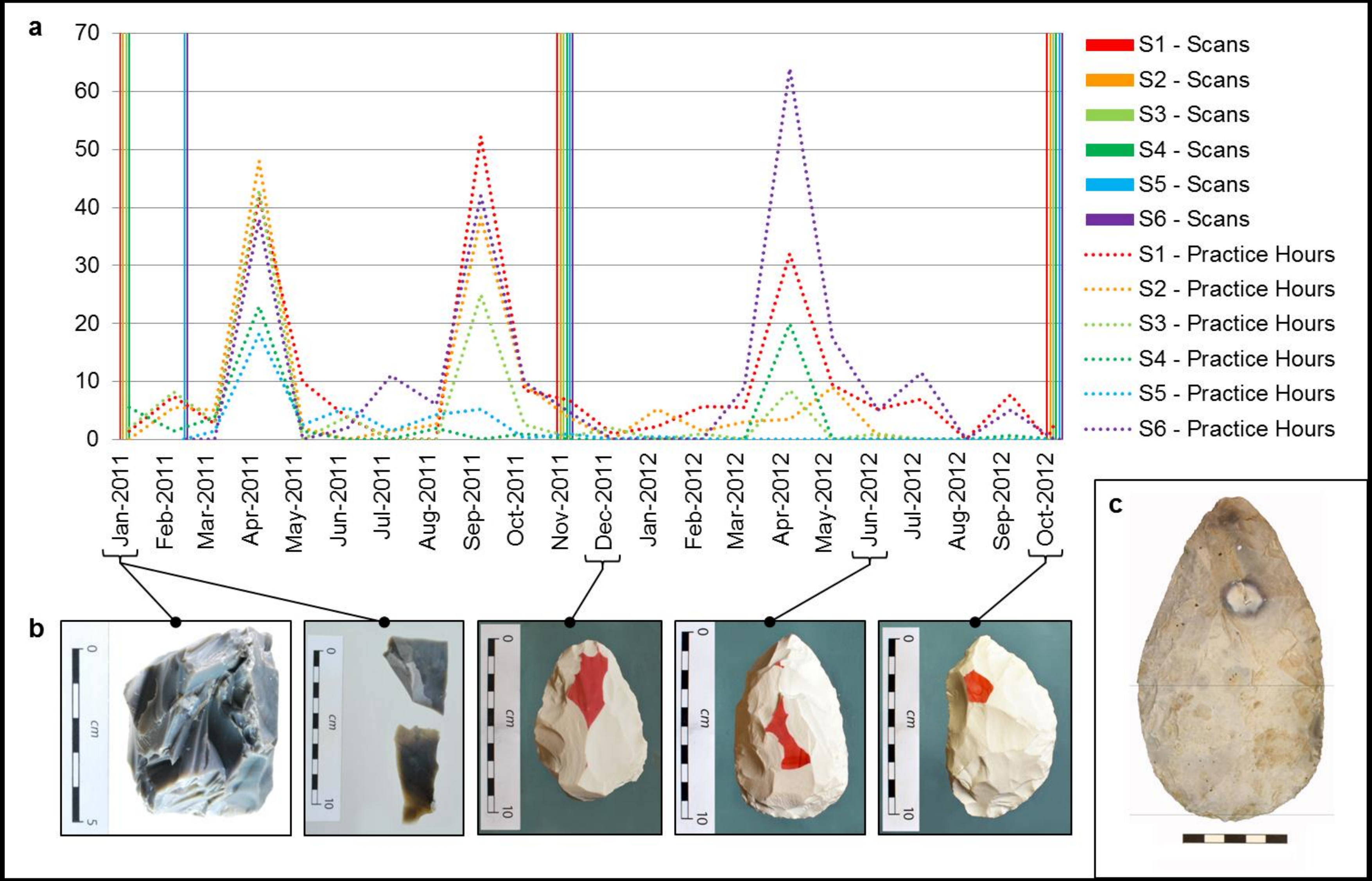
# 2. Brain changes during the acquisition of Paleolithic stone toolmaking

Which neural systems are forced to undergo change?

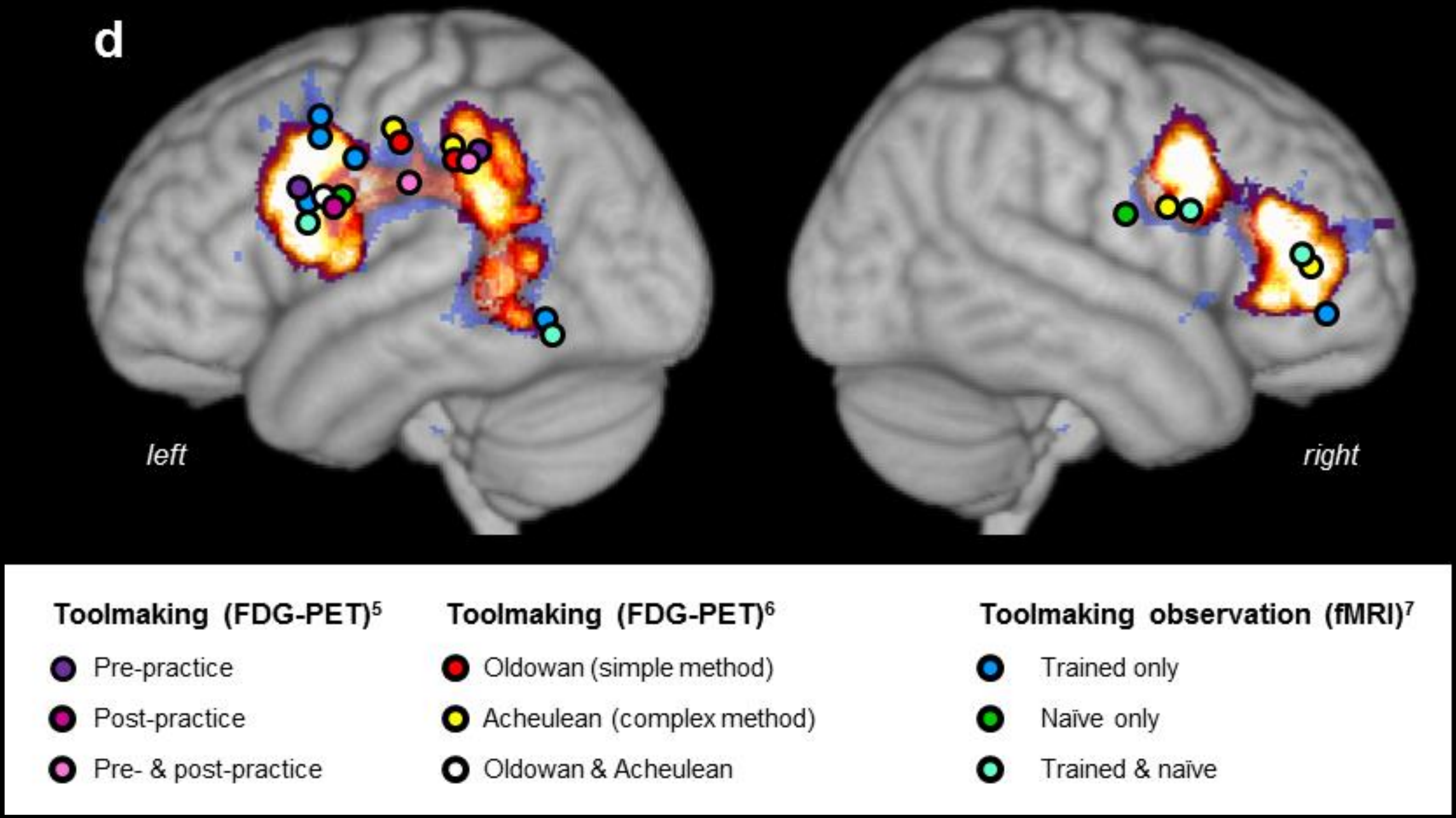
# Subjects learned to produce Paleolithic stone tools using archaeologically-attested methods



# 2 years of intensive training



# The regions that showed structural change overlap with regions that have been previously found to activate during Paleolithic stone toolmaking[1-3]




[7] *Stout, D. and T. Chaminade (2007). Neuropsychologia 45: 1091-1100.*
[8] *Stout, D., N. Toth, et al. (2008). Philos Trans R Soc Lond B Biol Sci 363: 1939-1949.*
[9] *Stout, D., R. Passingham, et al. (2011). Eur J Neurosci 33(7): 1328-1338.*