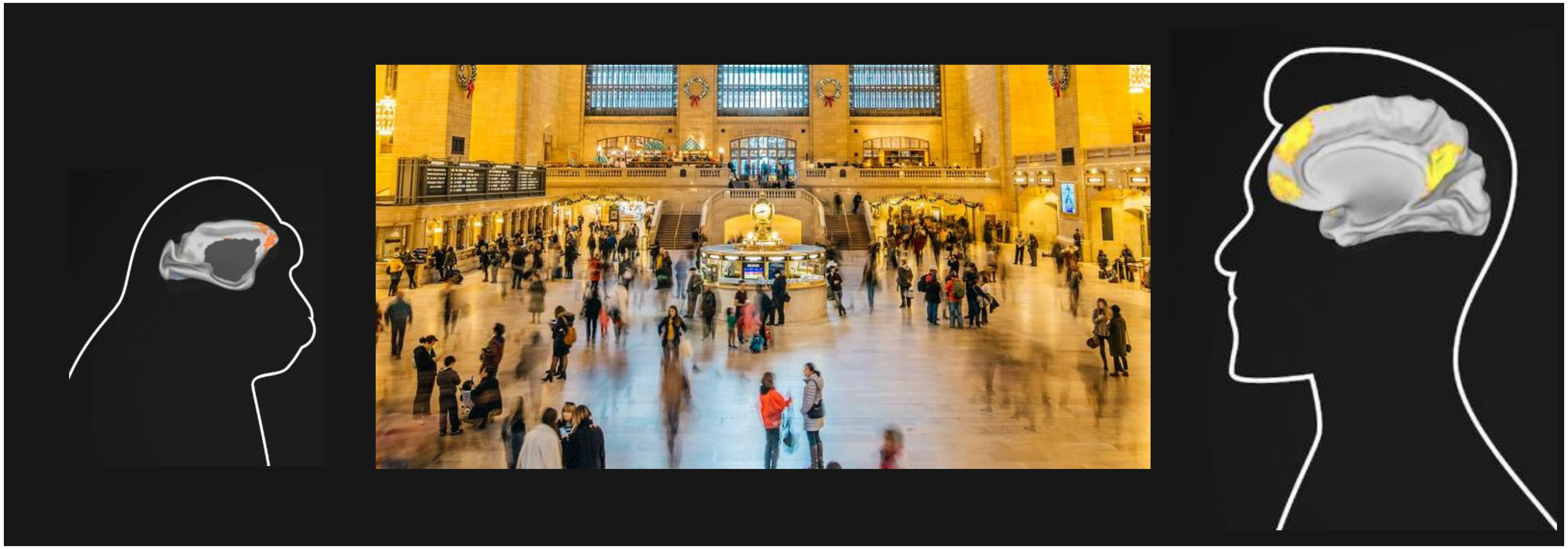
Primate brain networks for social processing

From agents, to actions, to interactions

JULIA SLIWA



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cnrs
ICM
Institut du Cerveau et de la Moelle épinière

We spend most of our time watching others

Most primates live in large social groups

Most primates live in large social groups

Rhesus Monkeys

Humans

Cognitive processes when watching social scenes

Rhesus Monkeys Humans

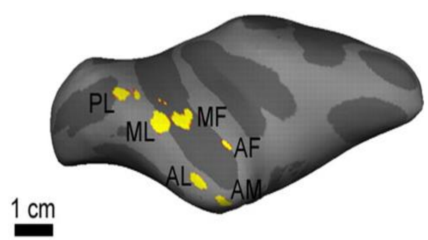
Agents

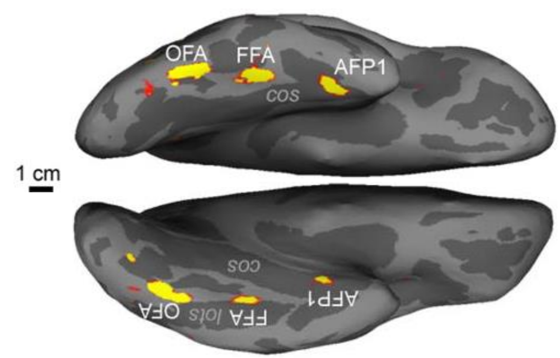
Cognitive processes when watching social scenes

Rhesus Monkeys

Humans

Agents



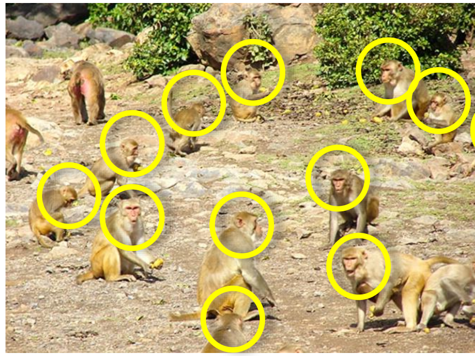


View of the brain from below

Tsao, Freiwald, et al. *Nat neuro* 2003

Kanwisher, et al. *J. neuro*. 1997

Cognitive processes when watching social scenes



Rhesus Monkeys

Humans

Agents

Individual recognition in rhesus monkeys

Sylvia Wirth, Jean-Rene Duhamel

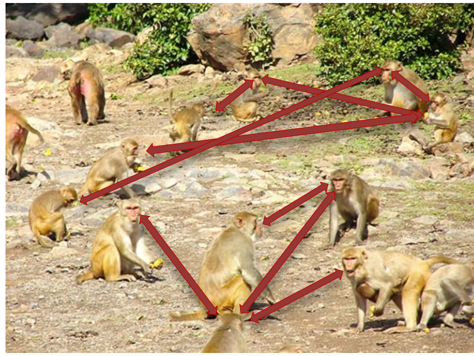
Institut des Sciences Cognitives – Marc Jeannerod
CNRS Lyon, France

Cognitive processes when watching social scenes

Rhesus Monkeys Humans

- ➢ Reveal hidden properties of agents (e.g. dominance, feelings, relationships…)

Cognitive processes when watching social scenes



Rhesus Monkeys

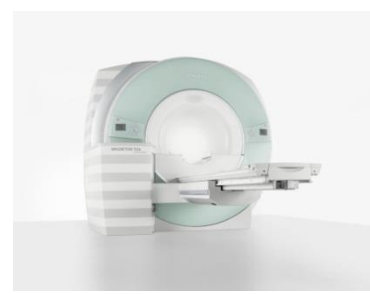
Humans

Agents

Action

Social Interaction

Processing social interactions



Winrich Freiwald

Rockefeller University, New York

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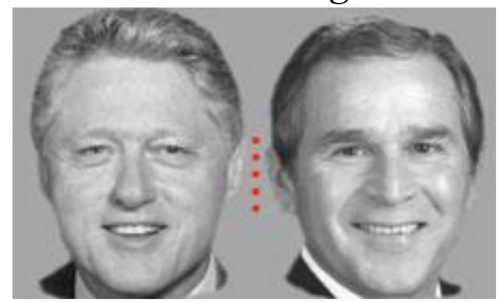
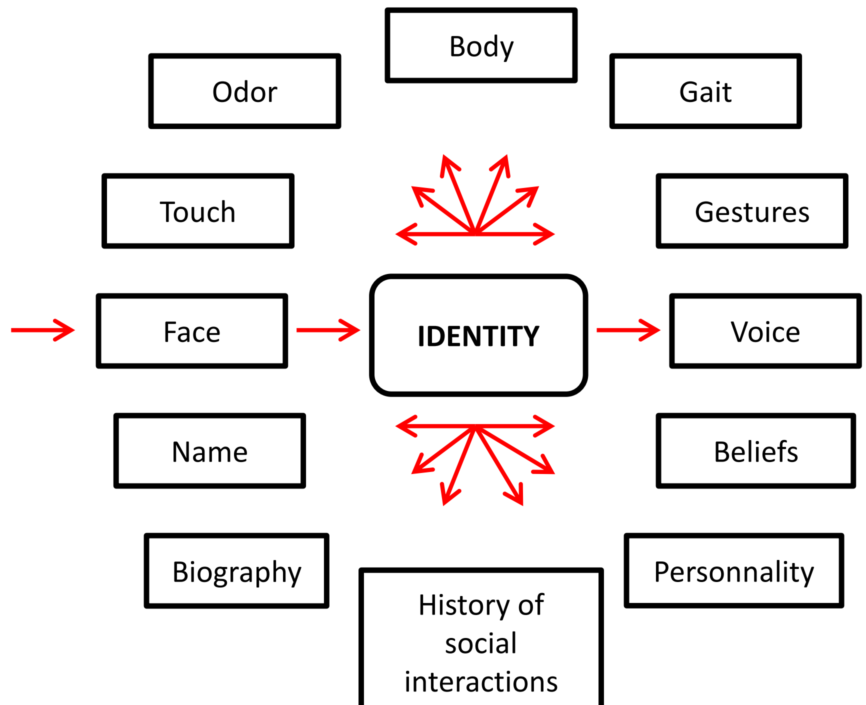
Individual recognition in rhesus monkeys

Discrimination

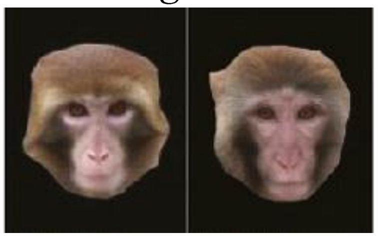
Individual recognition



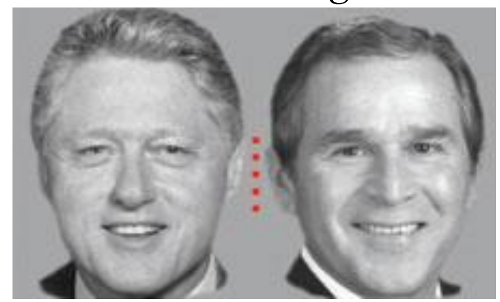


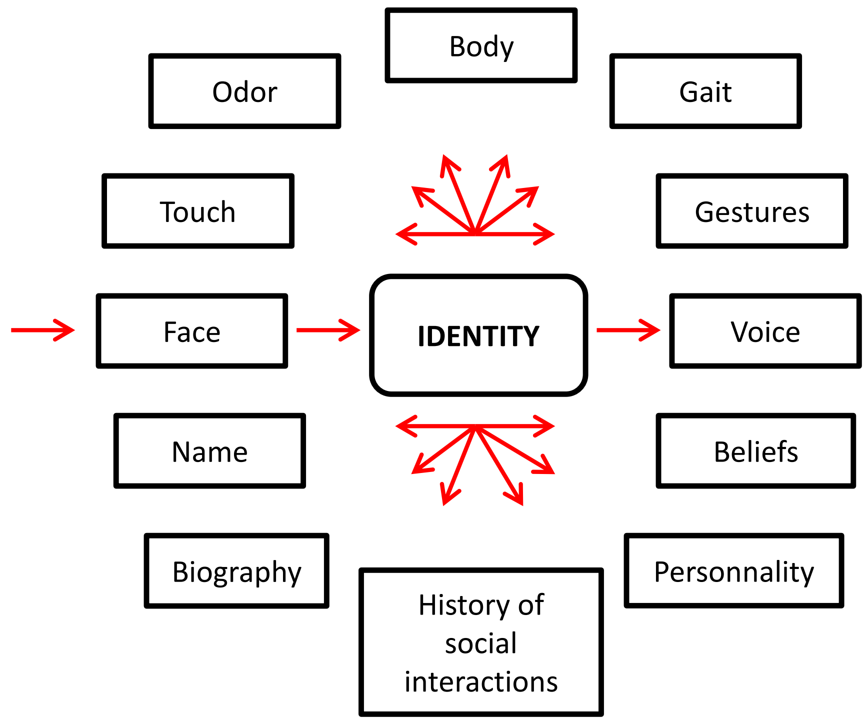
Individual recognition in rhesus monkeys

Individual recognition in monkeys?



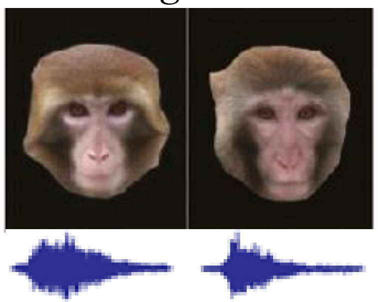
Individual recognition



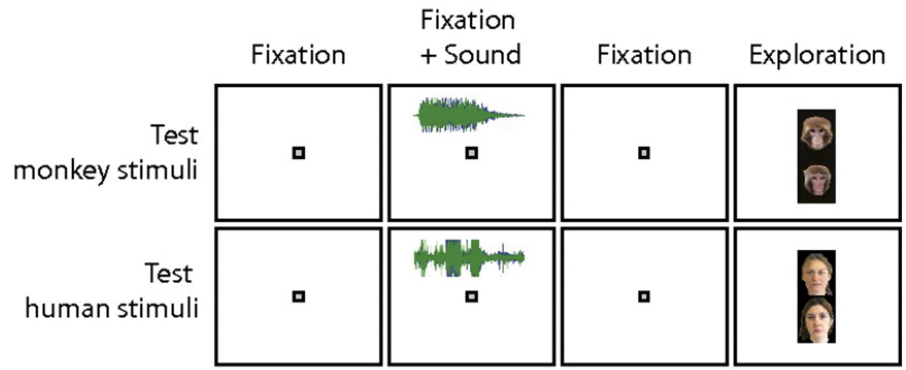


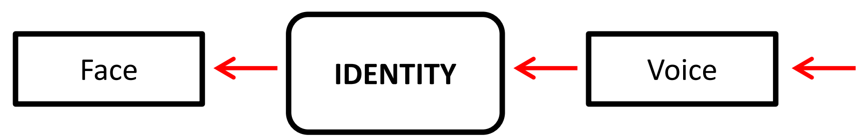
Individual recognition in rhesus monkeys

Individual recognition in monkeys?



Cross-modal sensory priming paradigm

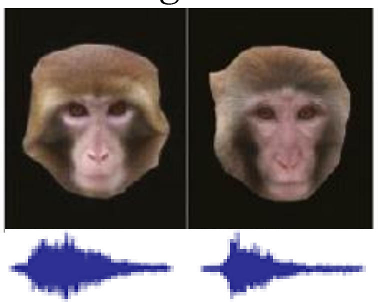




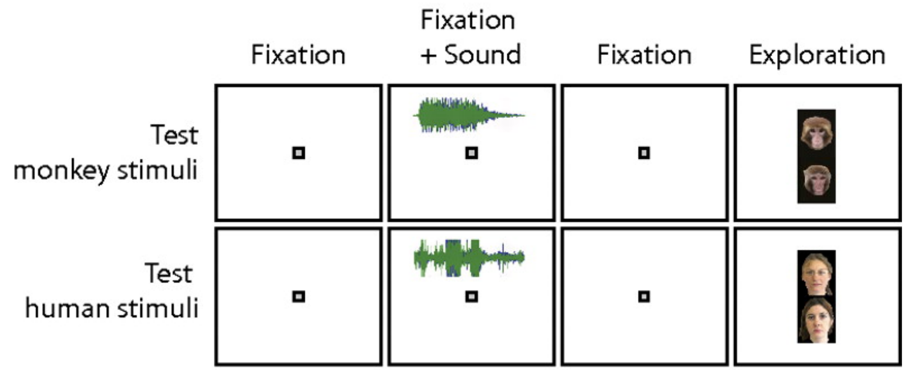
Sliwa *et al.*, PNAS, 2011

Individual recognition in rhesus monkeys

Individual recognition in monkeys?

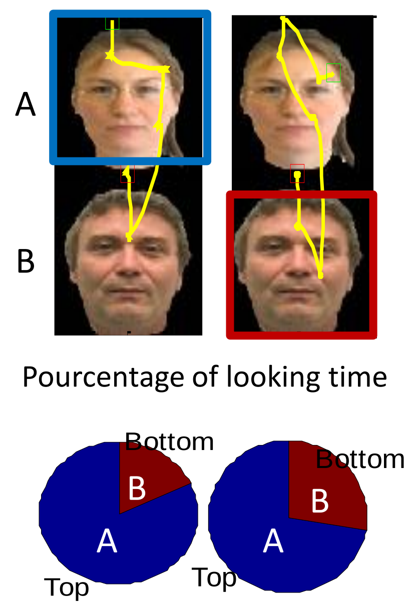


Cross-modal sensory priming paradigm

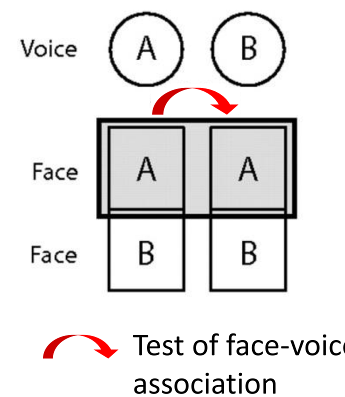


Cognitive representation of identity by rhesus monkeys

Face ↔ **IDENTITY** ↔ Voice



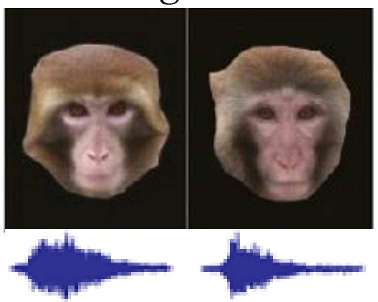
Comparisons of looking time



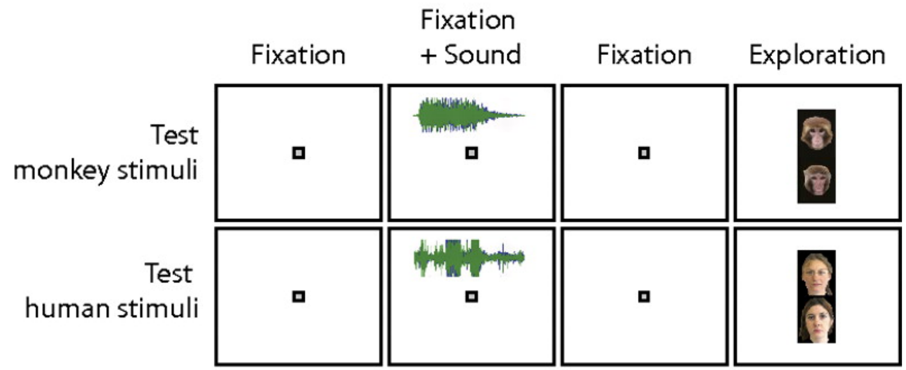
Sliwa *et al.*, PNAS, 2011

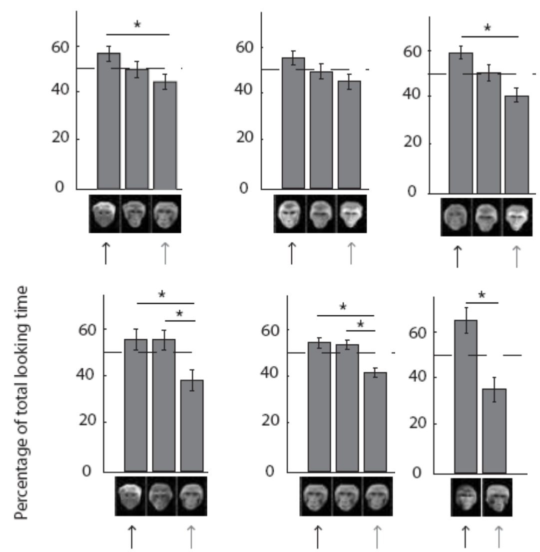
Individual recognition in rhesus monkeys

Individual recognition in monkeys?

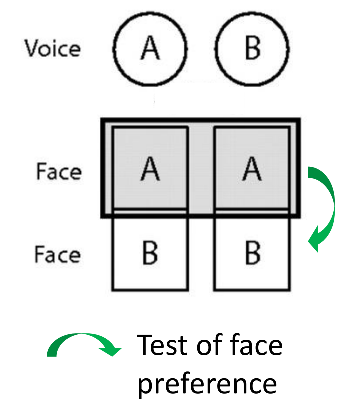


Cross-modal sensory priming paradigm





Comparisons of looking time



Cognitive representation of identity by rhesus monkeys

Face ↔ IDENTITY ↔ Voice

↕

History of past social interactions

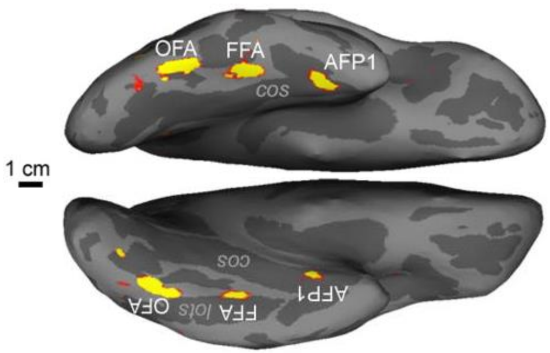
Sliwa *et al.*, PNAS, 2011

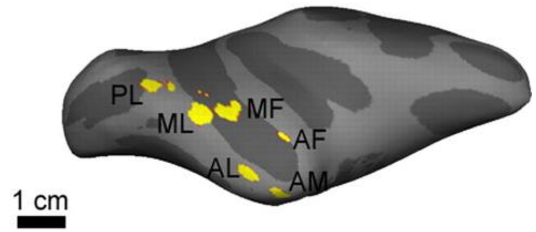
Neuronal bases of individual recognition?

Humans

Monkeys

Faces

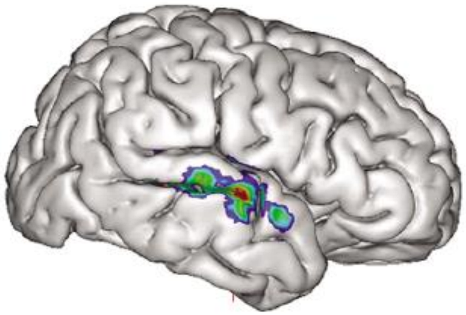


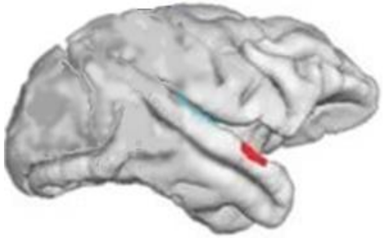


Kanwisher, et al. *J. neuro*. 1997
Tsao et al, *PNAS* 2008

Tsao, Freiwald, et al. *Nat neuro* 2003

Voices



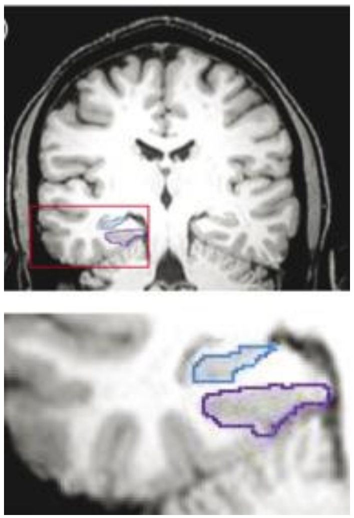


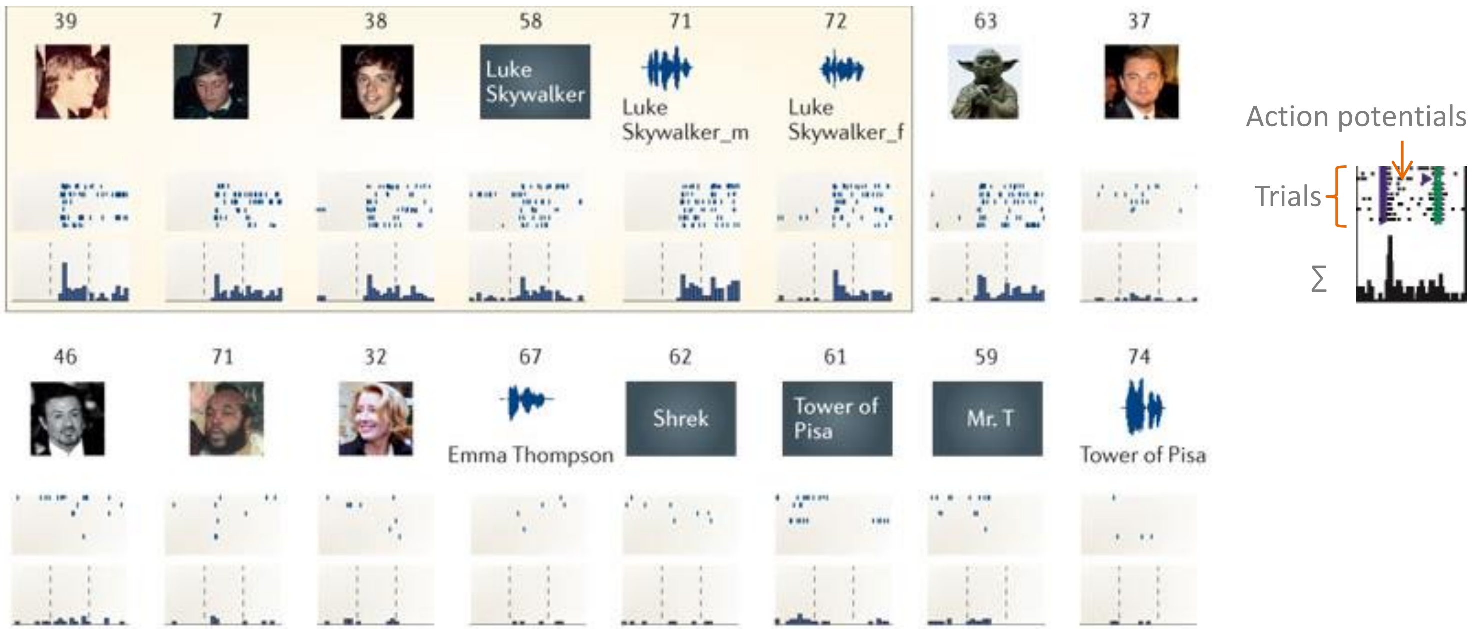
Belin et al., *Nat.* 2000

Petkov et al., *Nat. Neuro.*2008

Neuronal bases of individual recognition?

Human hippocampus

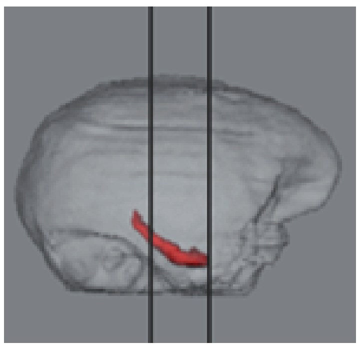


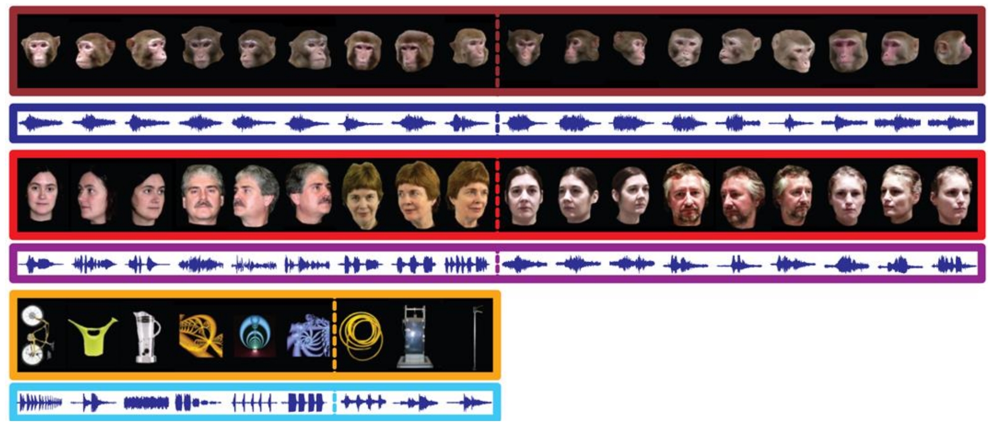


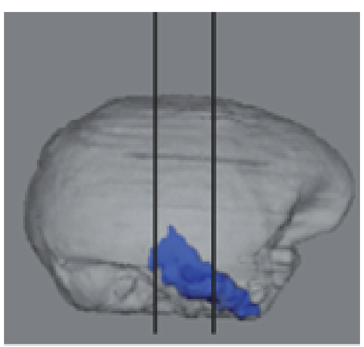
Quiroga, et al. *Nat.* 2005

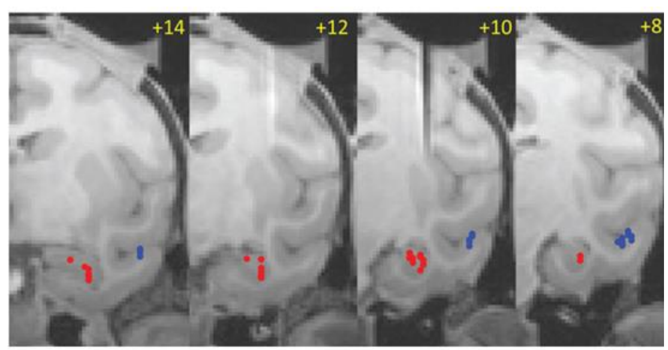
Neuronal bases of individual recognition?

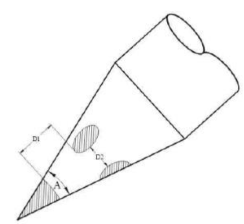
Monkey hippocampus ?

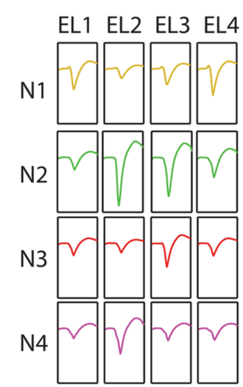










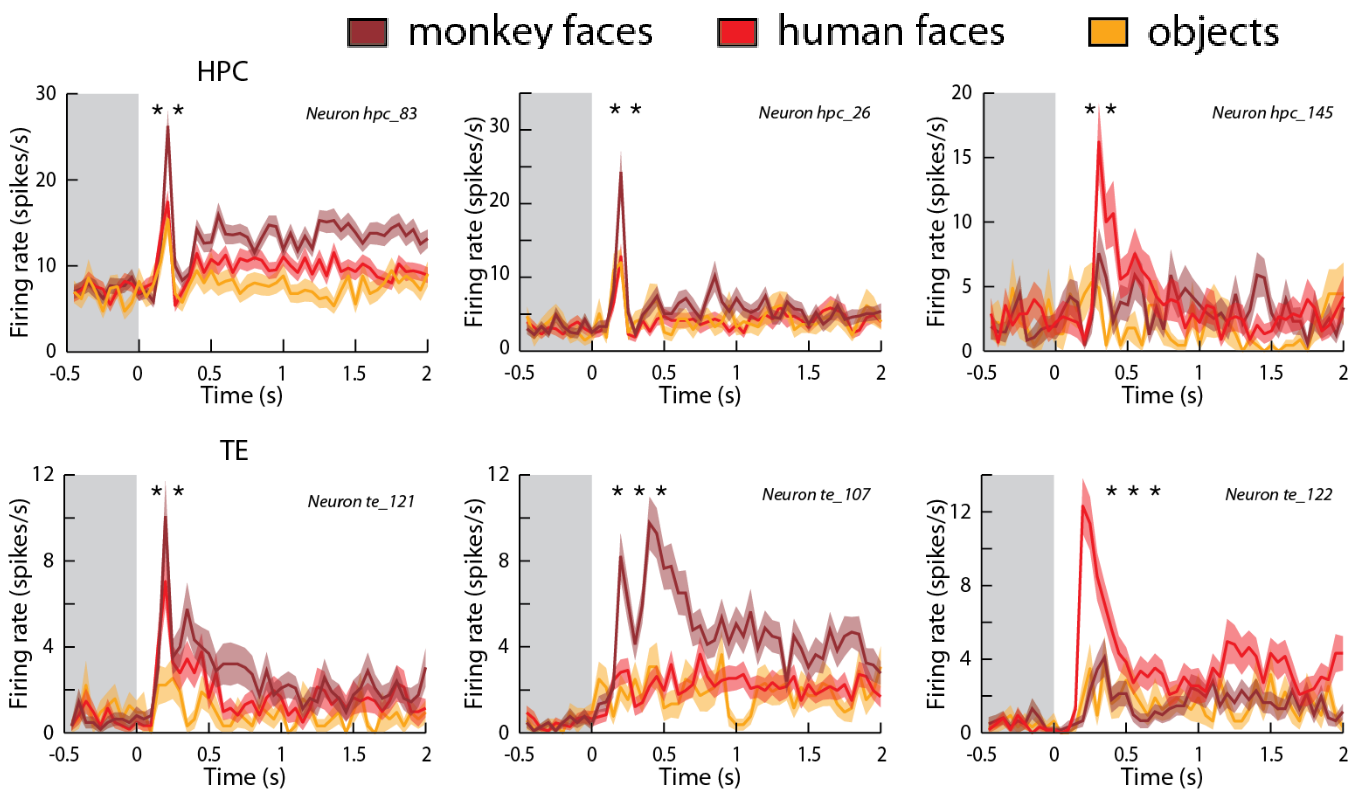


Sliwa, *et al*. Cer Cor 2014

Neuronal bases of individual recognition?

Hippocampus

Temporal cortex

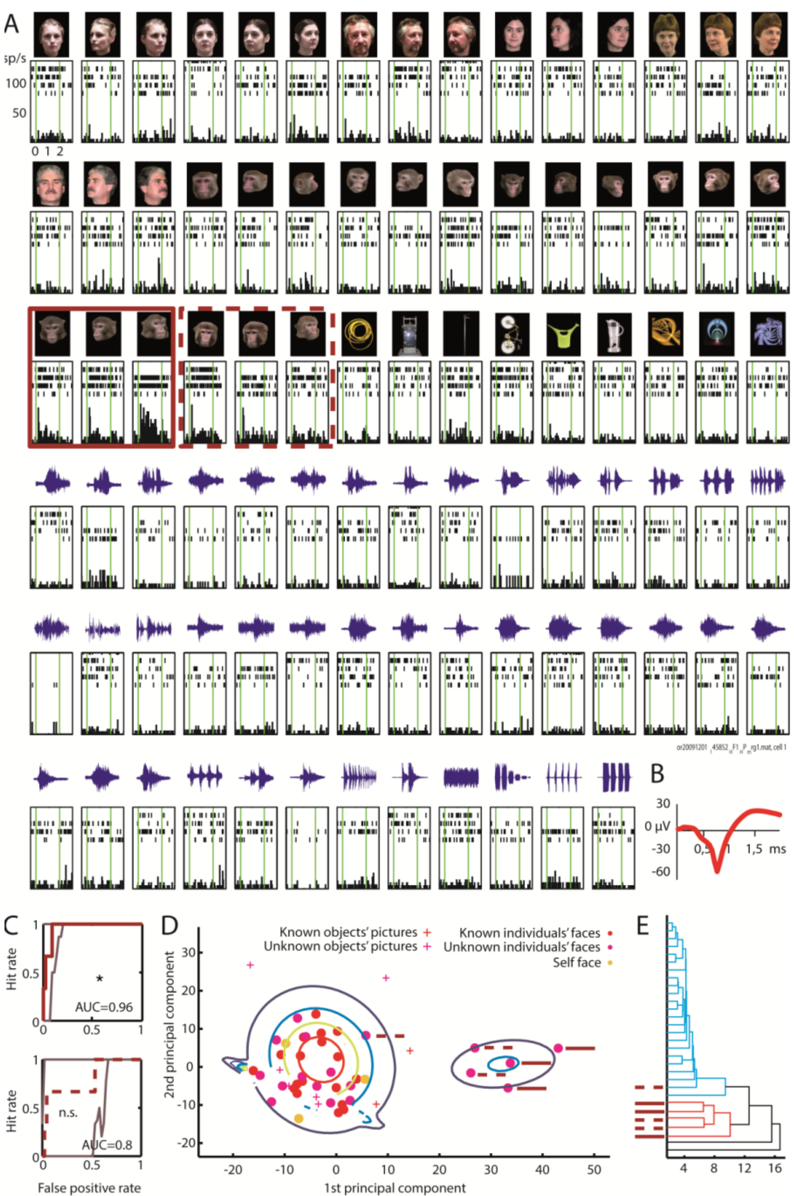


- ➢ Face-selective neurons in the hippocampus
- ➢ Representation of social information in the monkey hippocampus

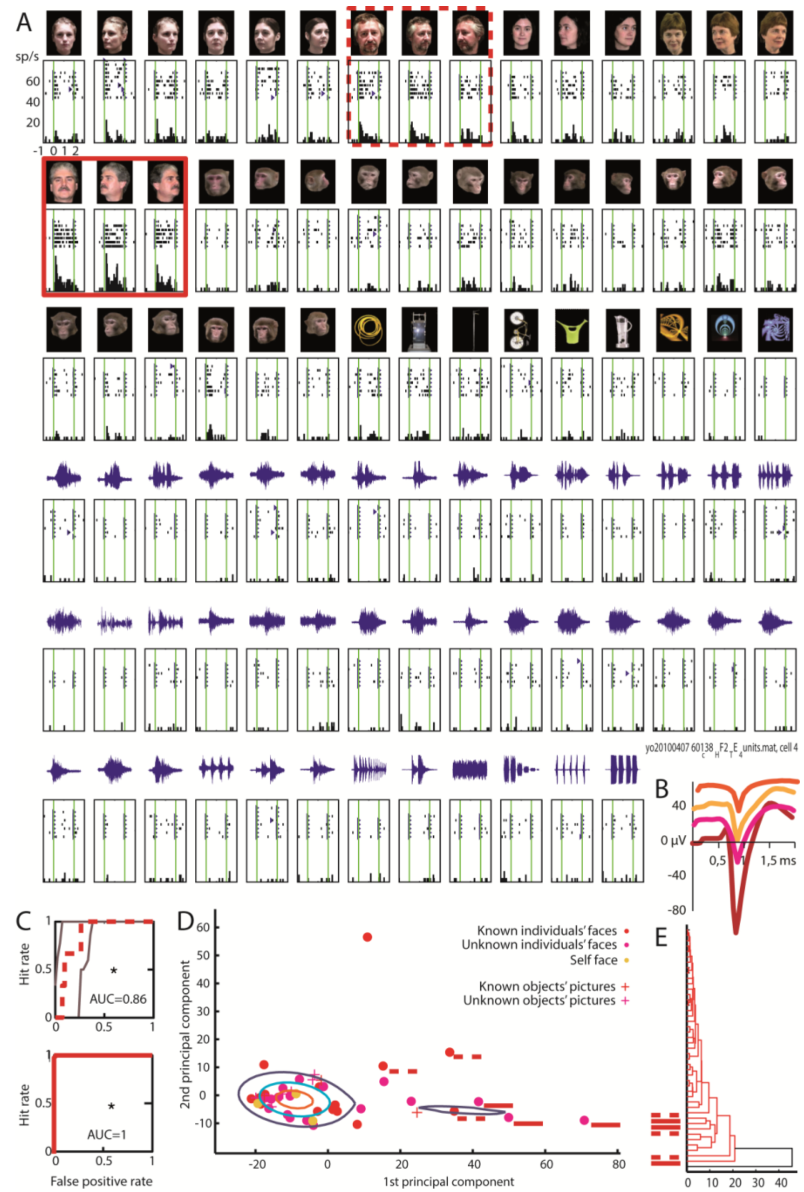
Sliwa, *et al*. Cer Cor 2014

Neuronal bases of individual recognition?

Hippocampus

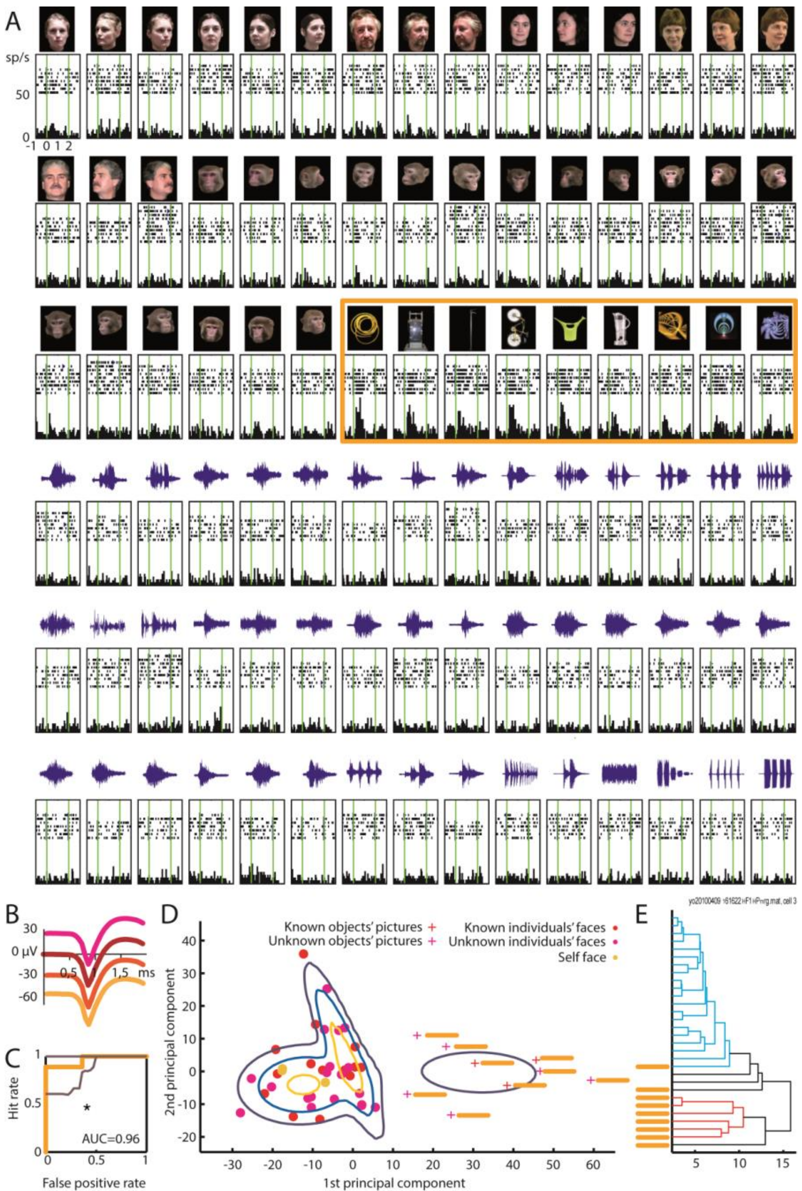


Temporal cortex



Neuronal bases of individual recognition?

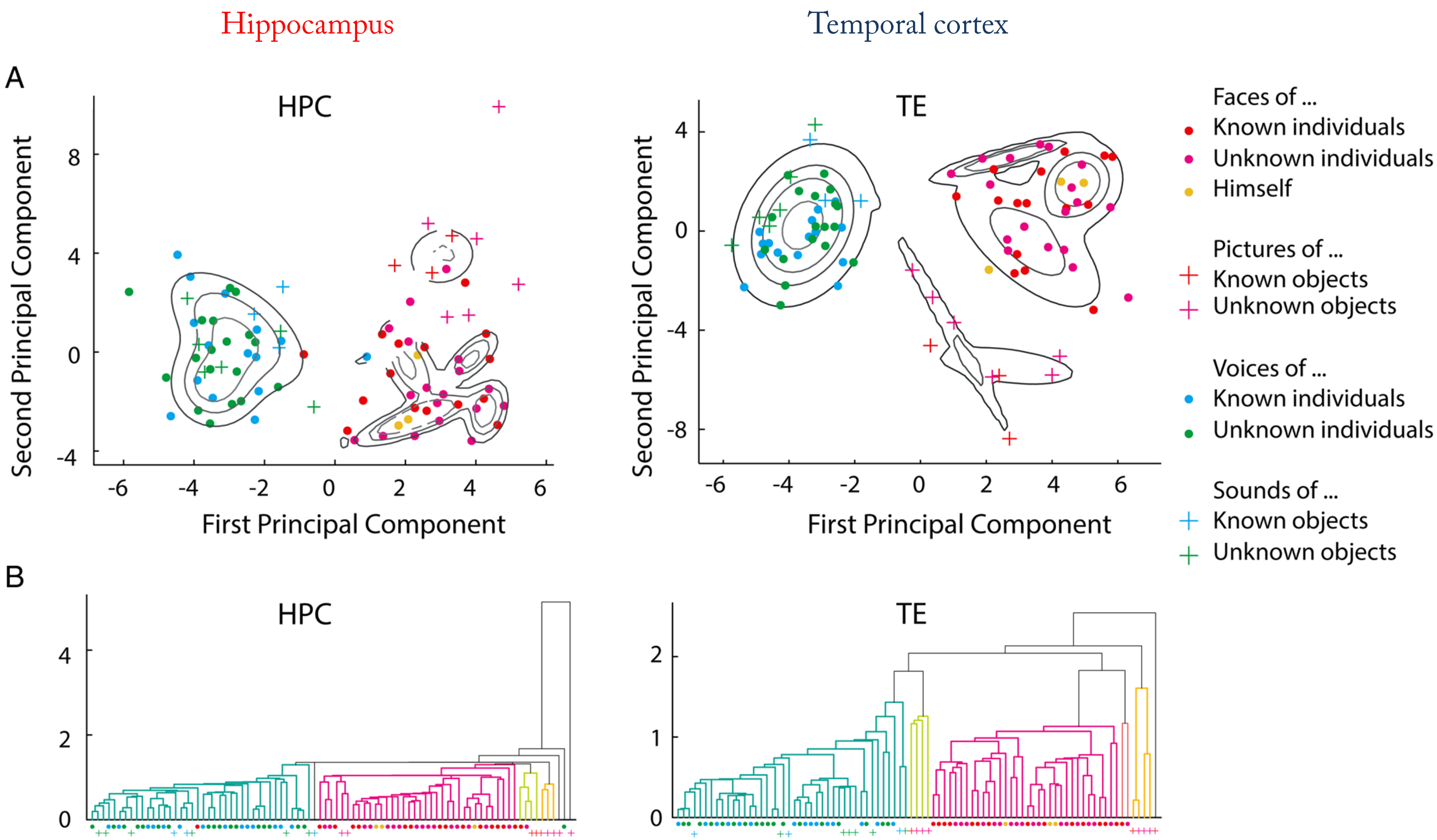
Hippocampus



- ➢ Invariant representation in the visual domain that do not generalize to the auditory domain

Sliwa, *et al*. Cer Cor 2014

Neuronal bases of individual recognition?



- ➢ Neurons categorize *sounds* away from *visual* stimuli and faces away from objects
- ➢ Codes in the hippocampus and temporal cortex resembled each other in the monkey

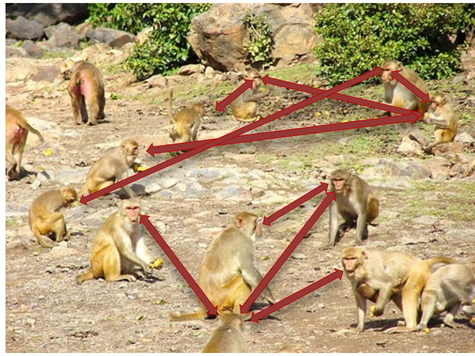
Sliwa, *et al*. Cer Cor 2014

Individual recognition in rhesus monkeys

Rhesus Monkeys Humans

1. Rhesus monkeys individually recognize their peers
2. Face-selective view-invariant neurons in the hippocampus
3. Invariant representations in the visual domain did not generalize to the auditory domain

Cognitive processes when watching social scenes



Rhesus Monkeys

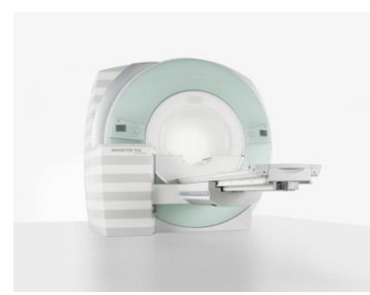
Humans

Agents

Action

Social Interaction

Processing social interactions



Winrich Freiwald

Rockefeller University, New York

The Rockefeller University 1901 · PRO BONO HUMANI GENERIS · SCIENTIA

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Cognitive processes when watching social scenes

Rhesus Monkeys

Humans

Agents

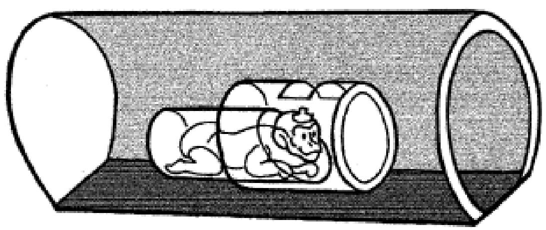
Action

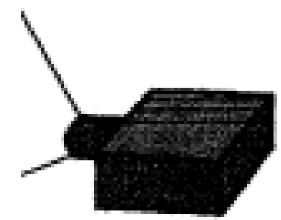
Social Interaction

→ Reveal something about our human nature?

- What we have in ***common*** with other primates and would be ancestral?
- What is ***specific*** to humans and sets us apart from other primates?

Studying the monkey brain using fMRI and naturalistic videos



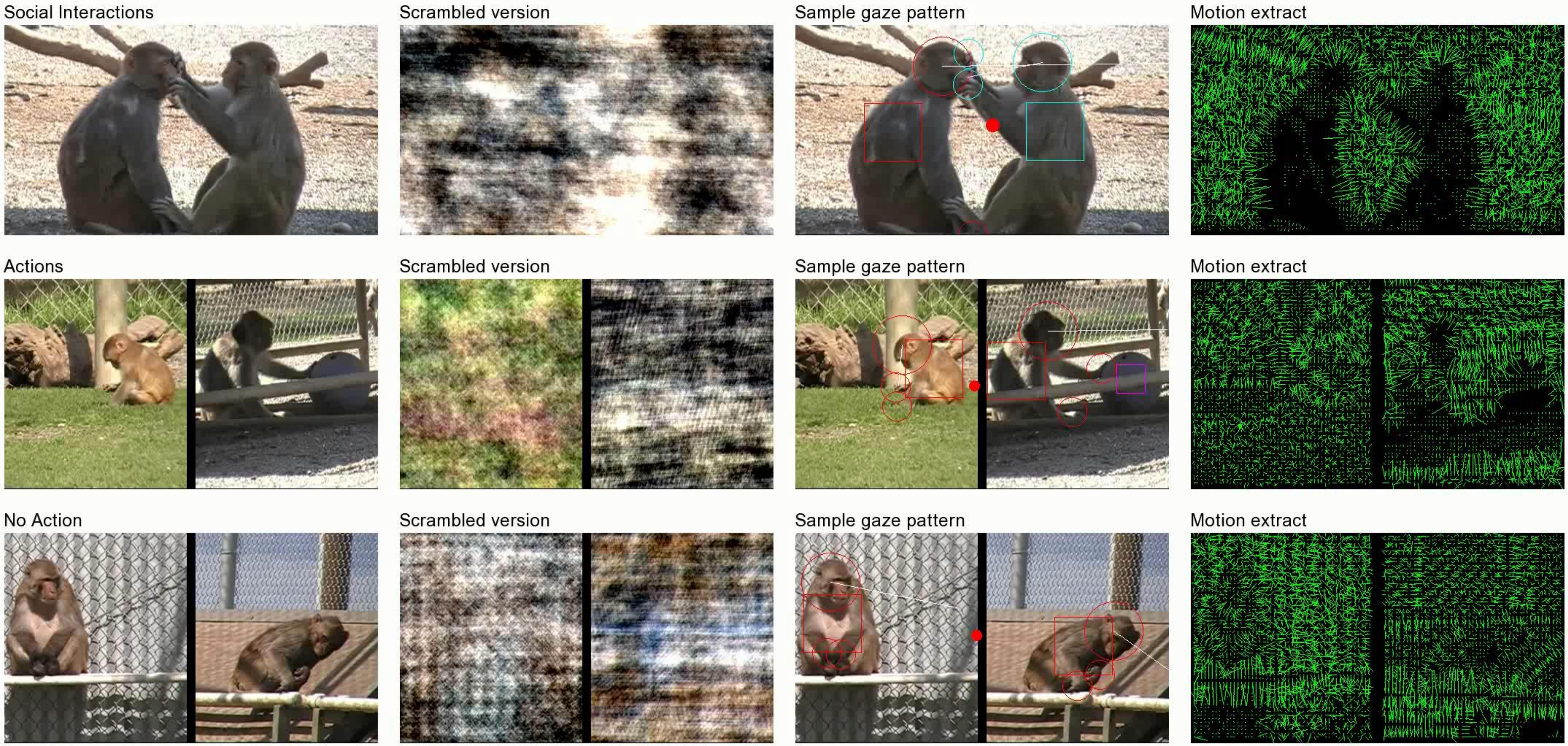


fMRI acquisition: horizontal slices with EPI sequence: TR 2s, TE 30ms 1.0 mm^3 voxel size, with MION contrast agent at 8mg Fe/kg

Sliwa & Freiwald, Science 2017

Studying the monkey brain using fMRI and naturalistic videos

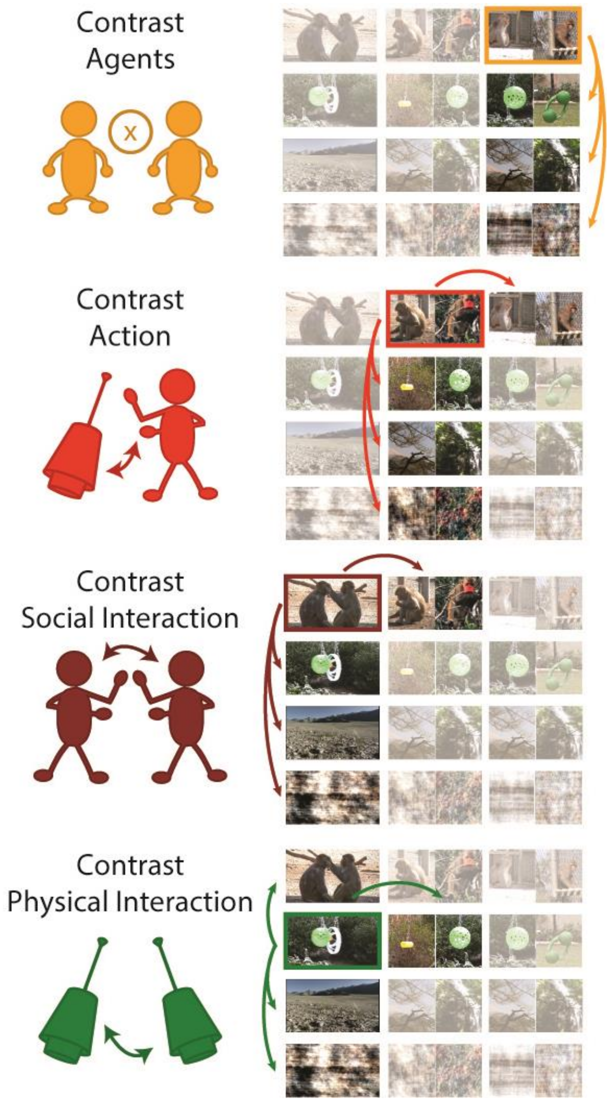
Videos | Control for motion | Gaze pattern | Motion quantification



Original videos by Machado and Amaral (UCSD) and from *Rhesus Play*

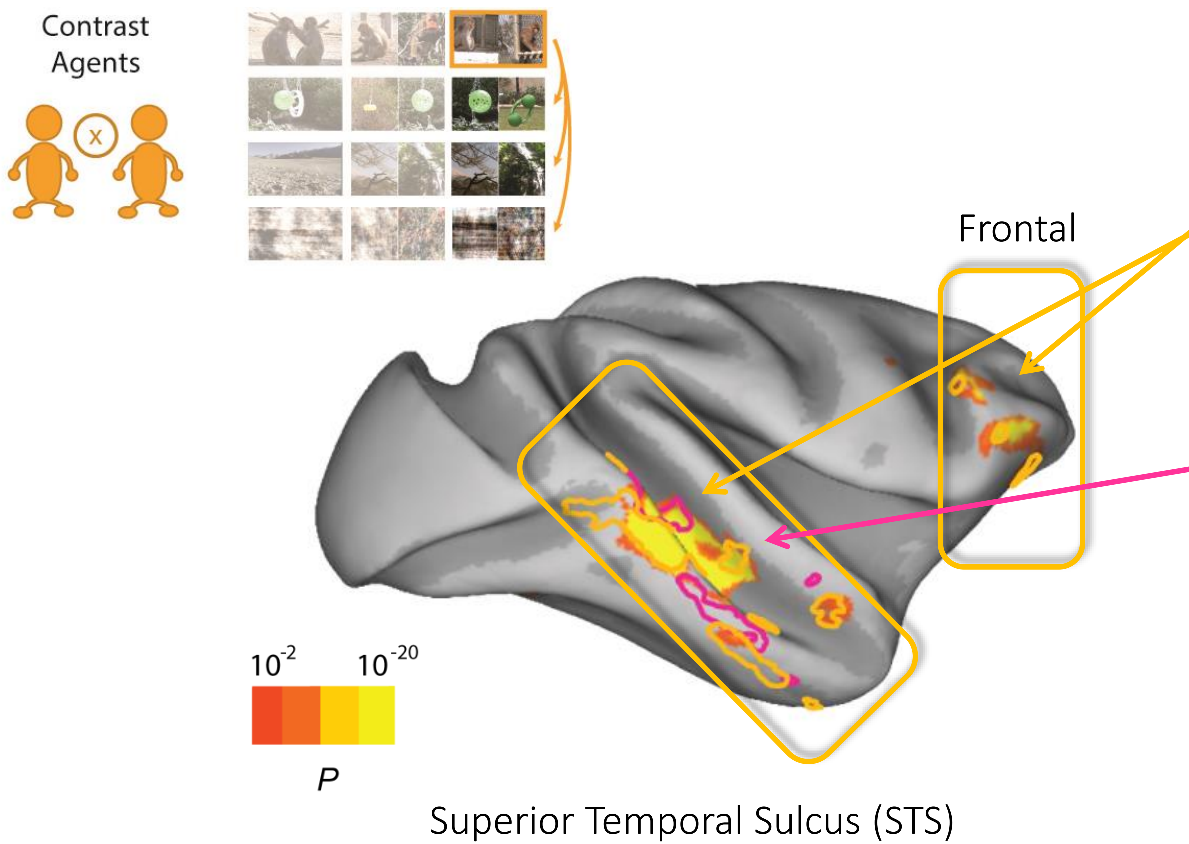
Sliwa & Freiwald, Science 2017

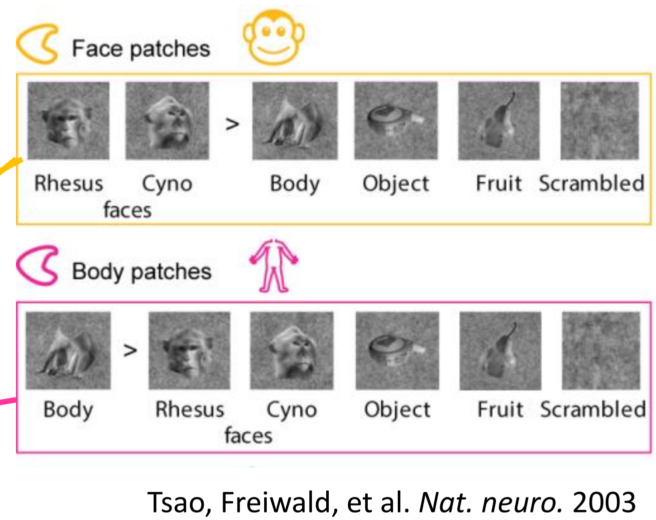
Studying the monkey brain using fMRI and naturalistic videos



Sliwa & Freiwald, Science 2017

Processing non-acting agents



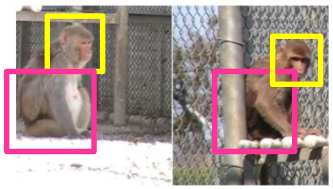


- Videos of non-acting monkeys in a naturalistic setting engage classical face and body areas

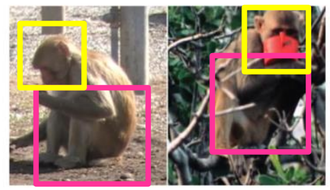
Sliwa & Freiwald, Science 2017

Face and body-selective areas are not only visual shape analyzers

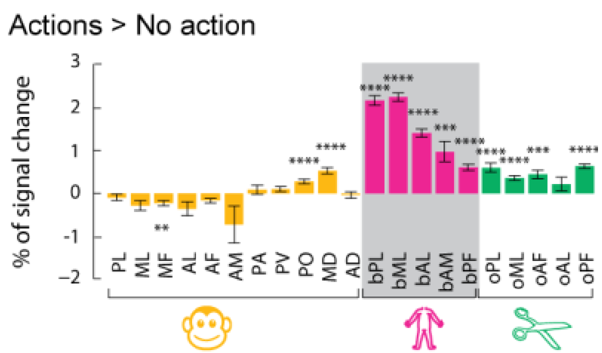
Not acting monkeys

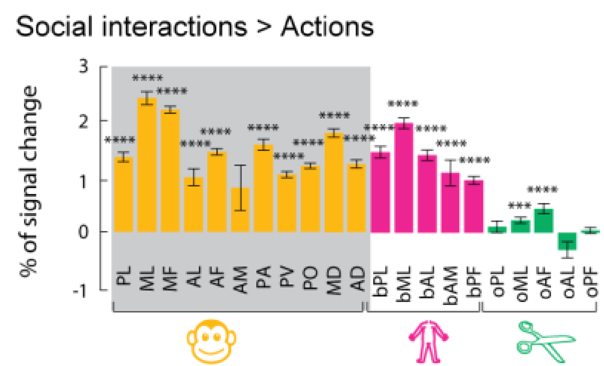


Acting monkeys



Social Interactions





- The type of social scene differently modulates basic mechanisms of face and body perception in the STS and frontal cortex

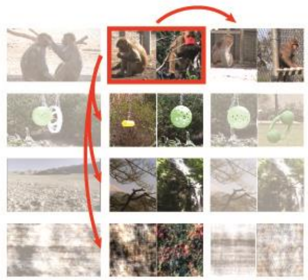
Sliwa & Freiwald, Science 2017

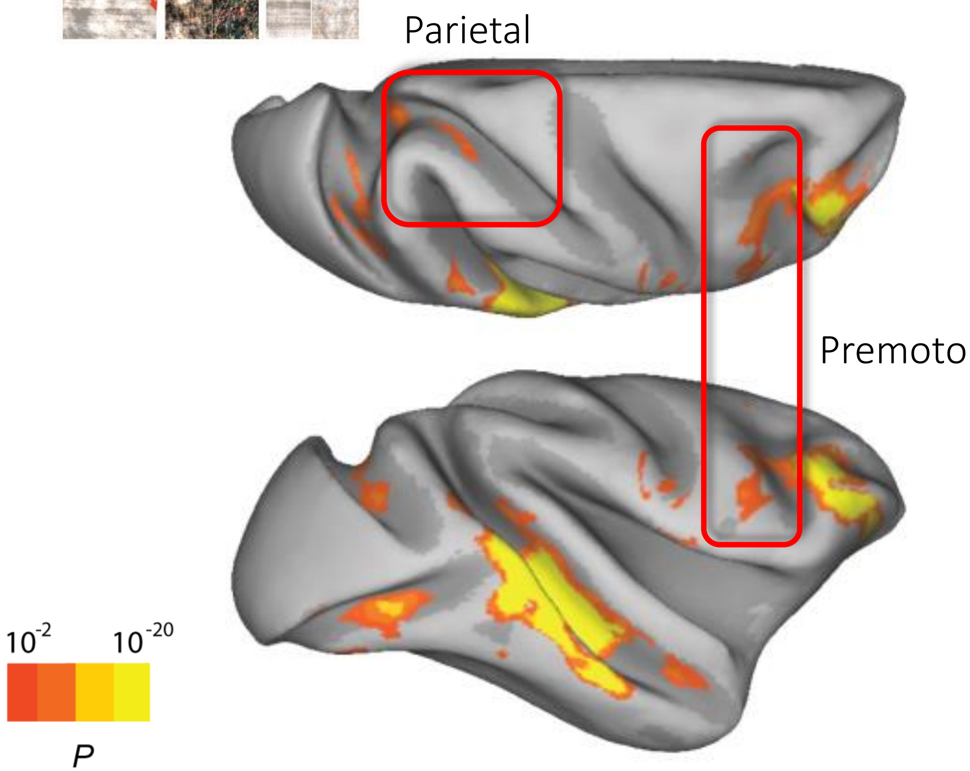
Processing Actions

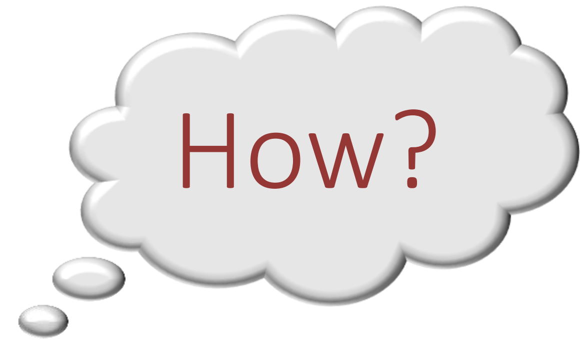
Sliwa & Freiwald, Science 2017

Processing Actions

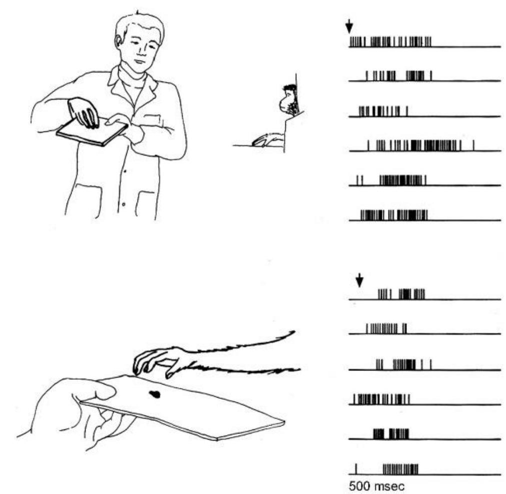
Contrast
Action







"Mirror Neurons"

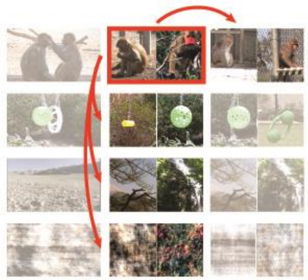


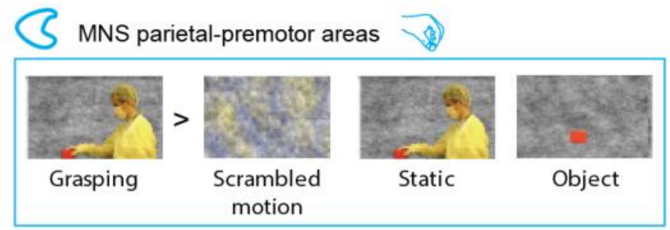
Di Pellegrino et al. *Exp Brain Res* 1992

Sliwa & Freiwald, Science 2017

Processing Actions

Contrast
Action

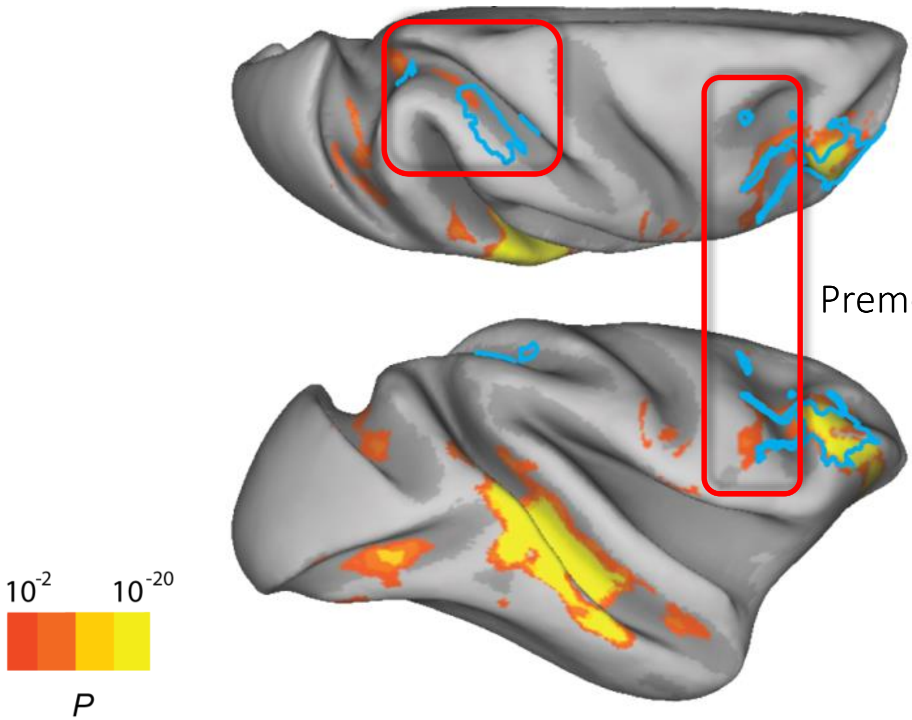




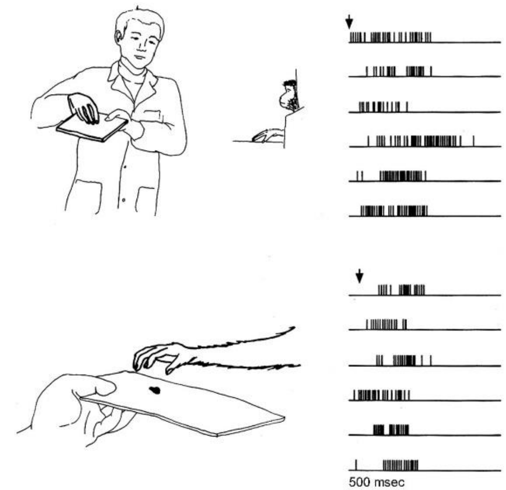
Adapted from Nelissen et al. *Science* 2005

Parietal

Premotor



"Mirror Neurons"

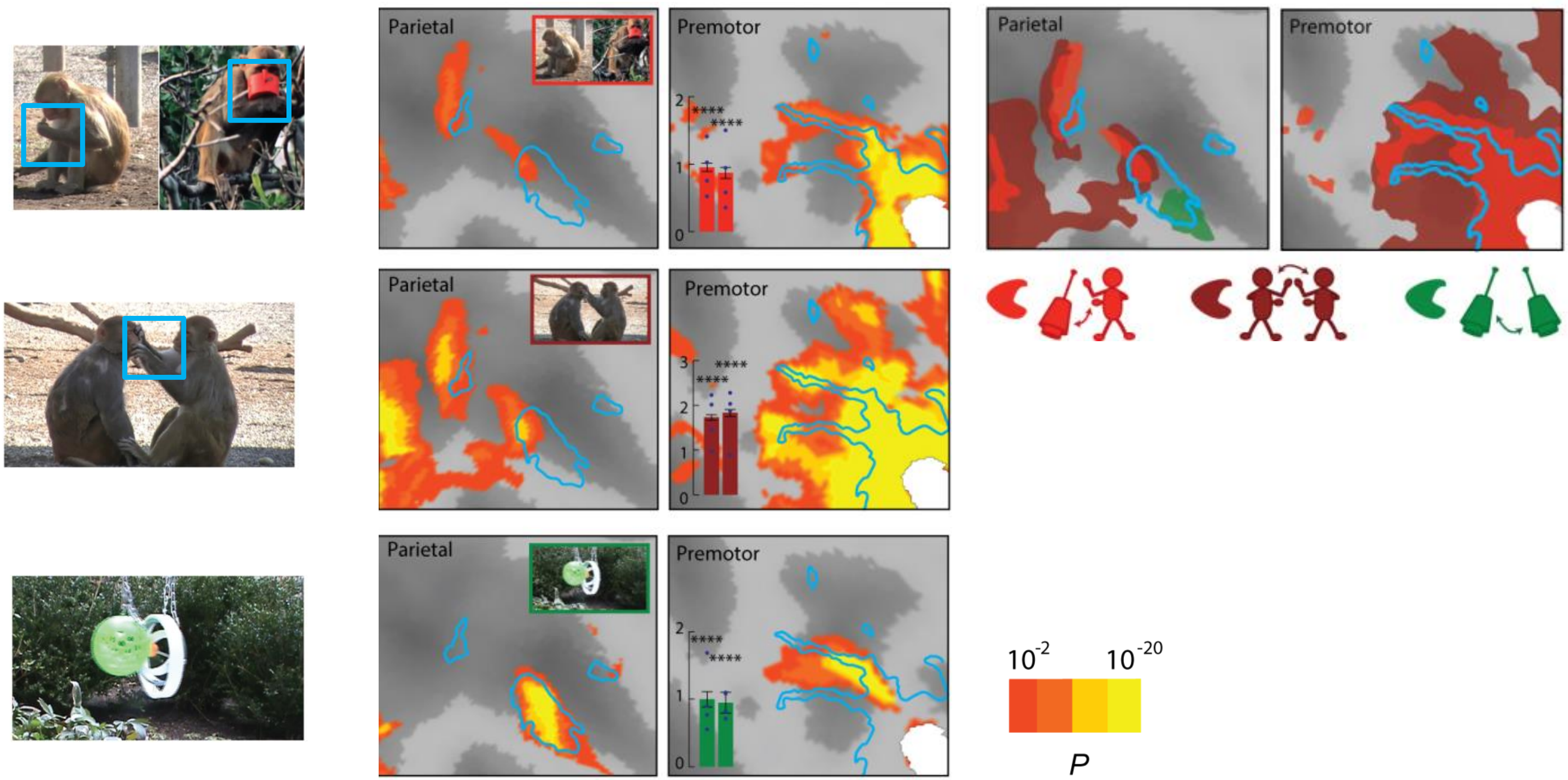


Di Pellegrino et al. *Exp Brain Res 1992*

- ➢ Videos of acting monkeys in a naturalistic setting engage the parieto-frontal cortex in areas overlapping with the Mirror Neuron System

Sliwa & Freiwald, Science 2017

The Mirror Neuron System as a generic analyzer of both social and physical interactions



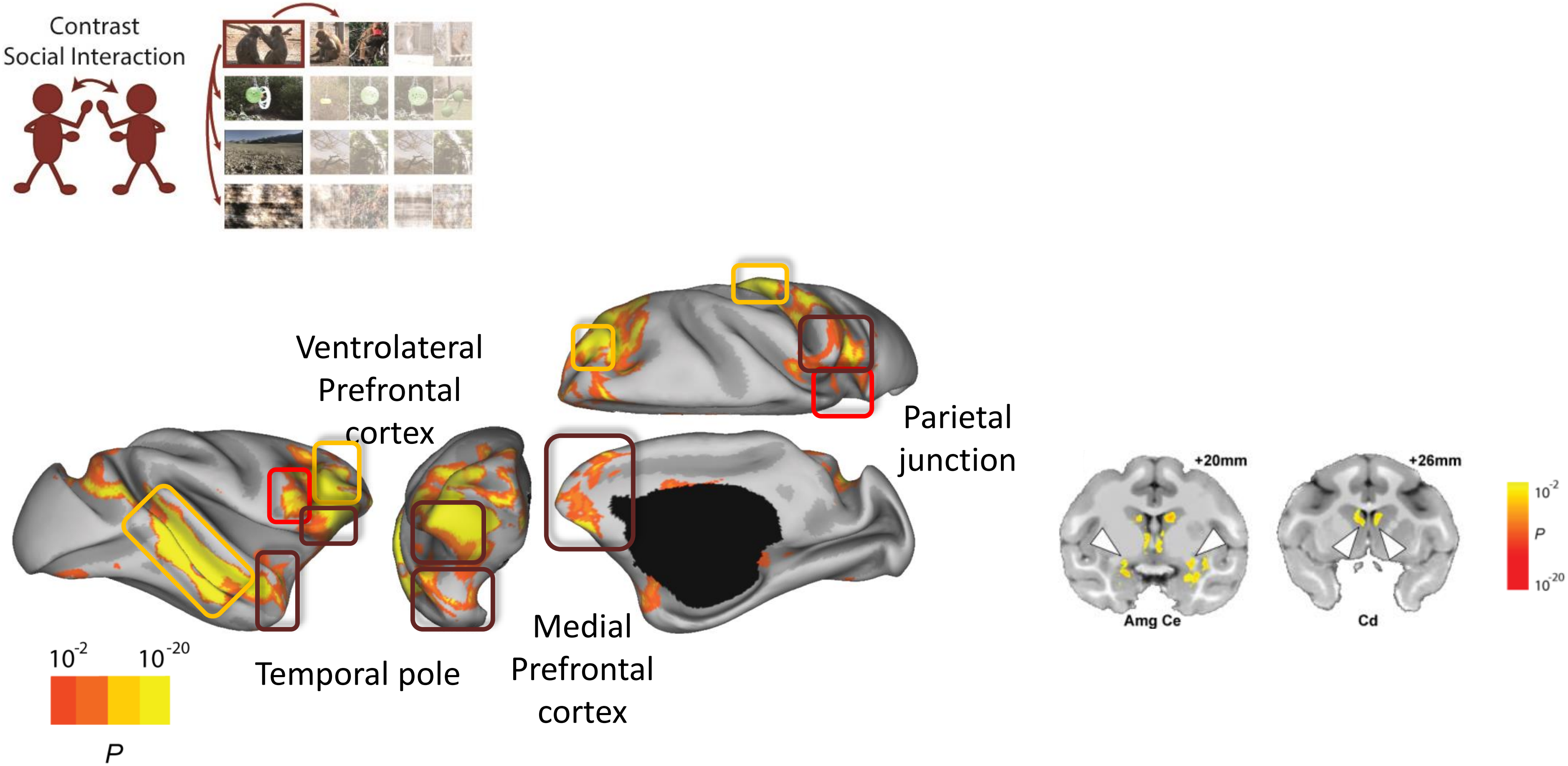
- ➢ The anterior part of parietal MNS appears specifically activated by physical interactions
- ➢ A broader role of the MNS for social and physical world simulation

Sliwa & Freiwald, Science 2017

Processing social interactions

Sliwa & Freiwald, Science 2017

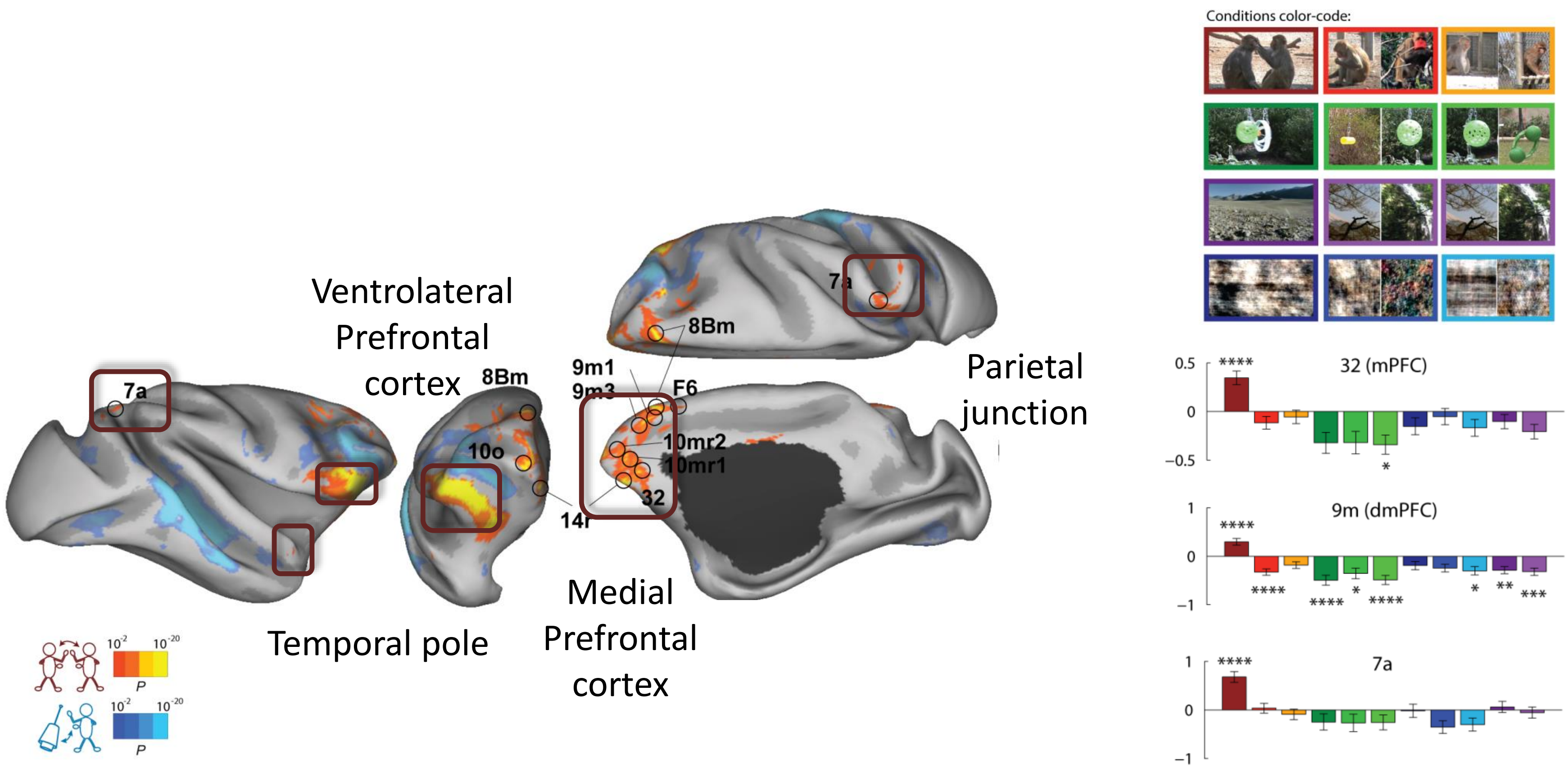
Processing social interactions



➢ Showing the specific aptitude of primate brains for extracting social information from interactions.

Sliwa & Freiwald, Science 2017

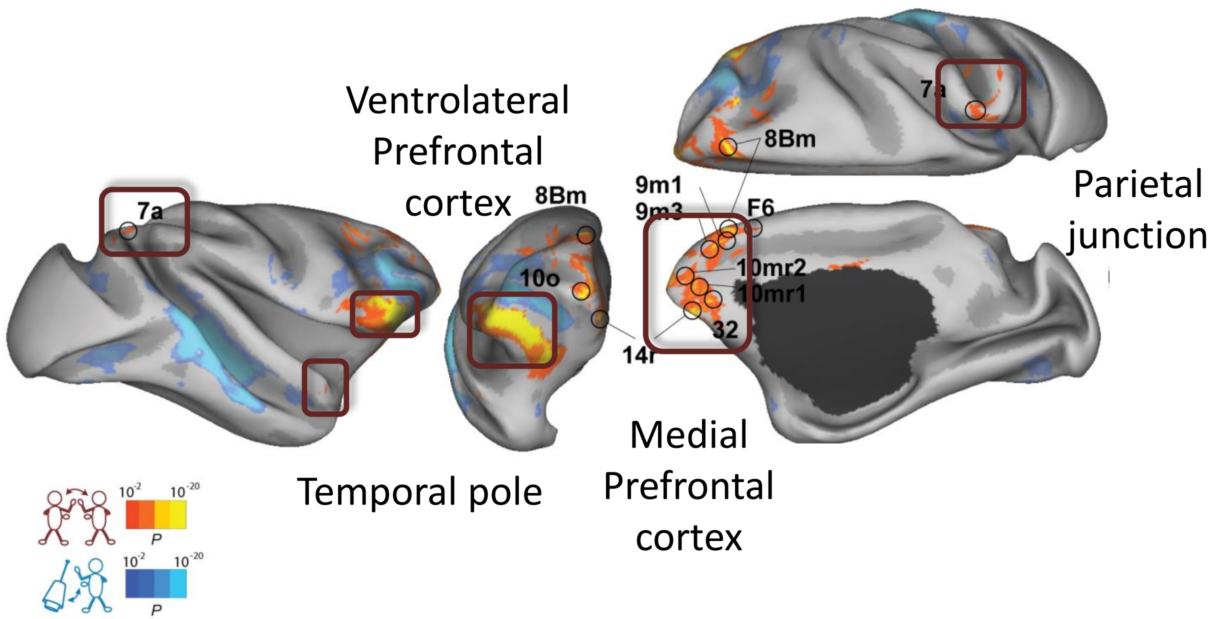
A network for social interaction processing

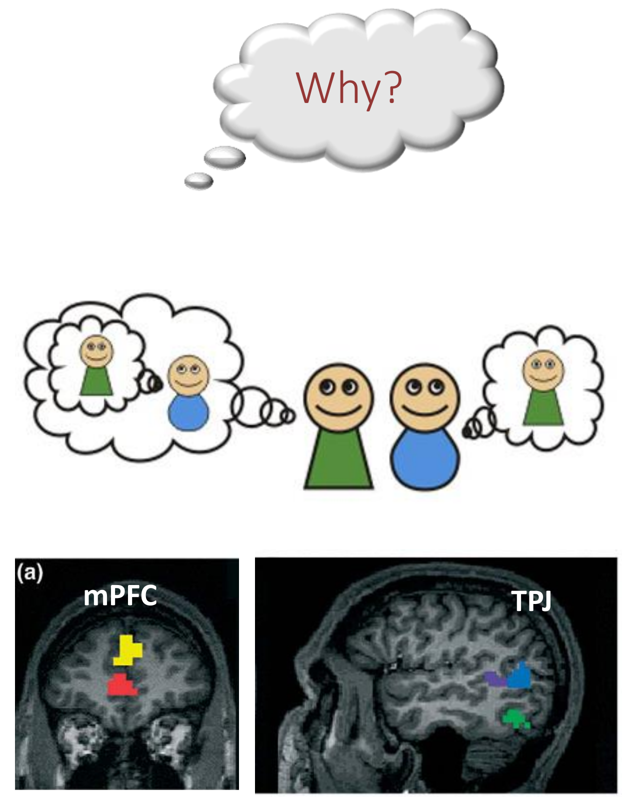


- ➢ Regions of the monkey brain engaged selectively for social interaction analysis
- ➢ A property reminiscent of the Default Mode Network in human

Sliwa & Freiwald, Science 2017

A network for social interaction processing



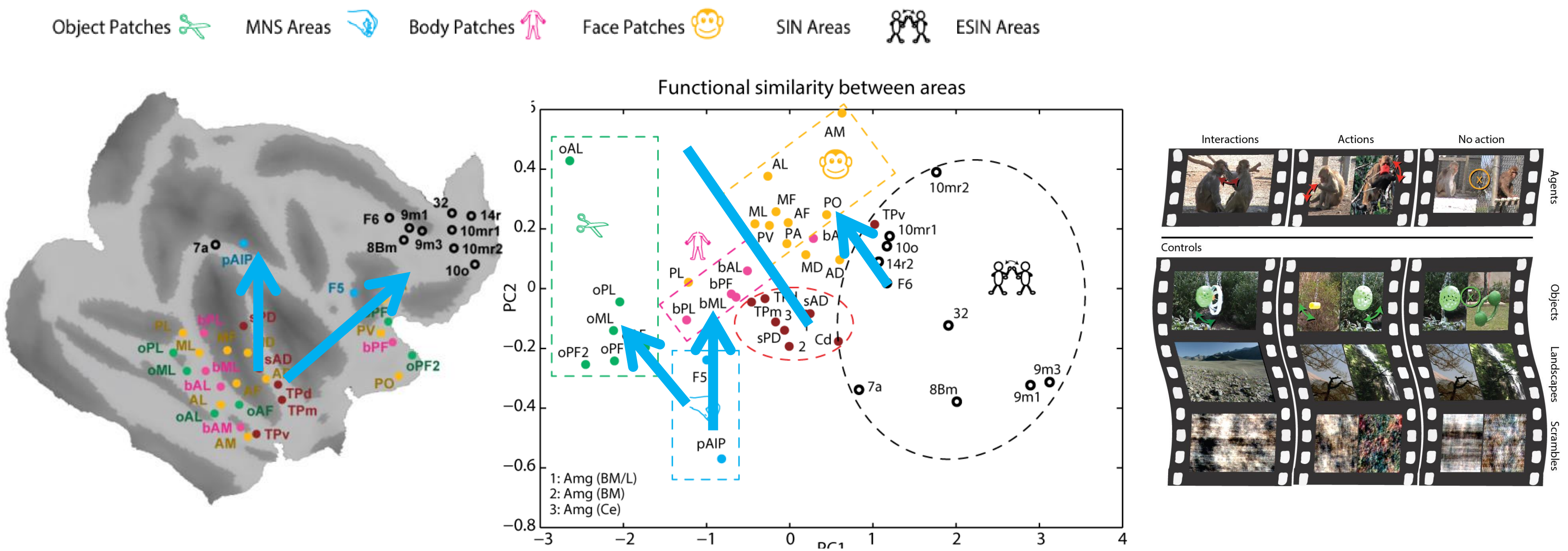


Saxe, *Curr Op Neurobiol*, 2006

- Located in areas homologous to the human theory of mind network
- Monkeys have limited theory of mind abilities (Santos et al.)
- Processing social interactions could be a putative precursor of our ToM ability

Sliwa & Freiwald, Science 2017

How do these networks relate to each other?



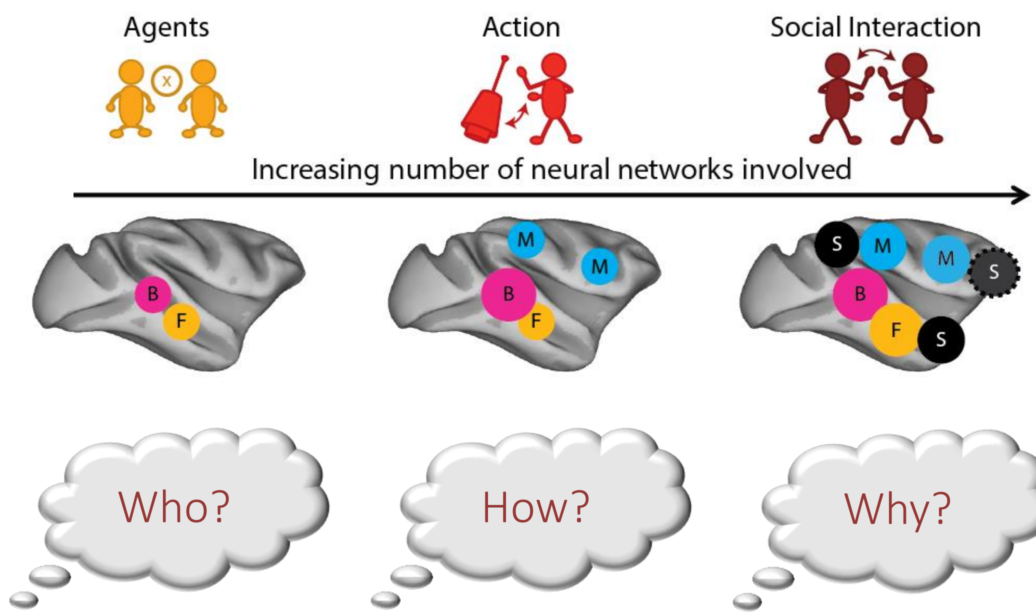
- ➢ Face and body areas cluster separately by their responses to the different videos
- ➢ The MNS differs substantially from the (E)SIN , and is more similar to object and body patches.
- ➢ Greater similarity of face patches to the ESIN than any other patches, suggesting these areas as putative entry points to the ESIN.
- ➢ Two streams segregating in the STS

Sliwa & Freiwald, Science 2017

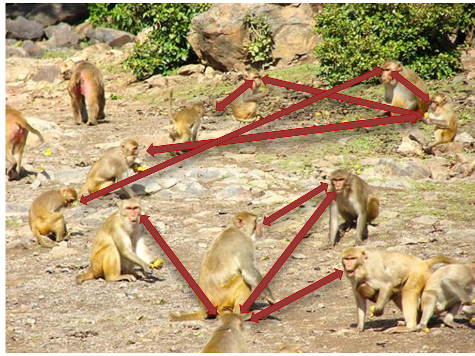
Cognitive processes when watching social scenes

Rhesus Monkeys Humans

- *face areas and body areas*
- *mirror neuron system*
- proto- *theory of mind network*



Cognitive processes when watching social scenes

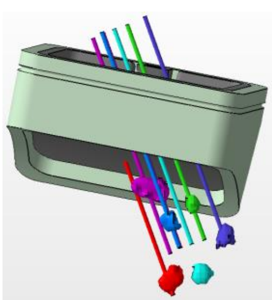


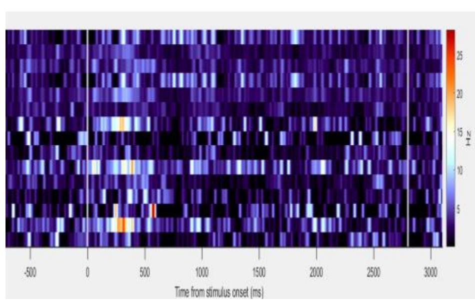
Rhesus Monkeys

Humans

fMRI targeted electrophysiological recordings

Human fMRI





with F. Aboharb

with S. Marvel and G. Ianni

Cognitive processes when watching social scenes

Rhesus Monkeys Humans

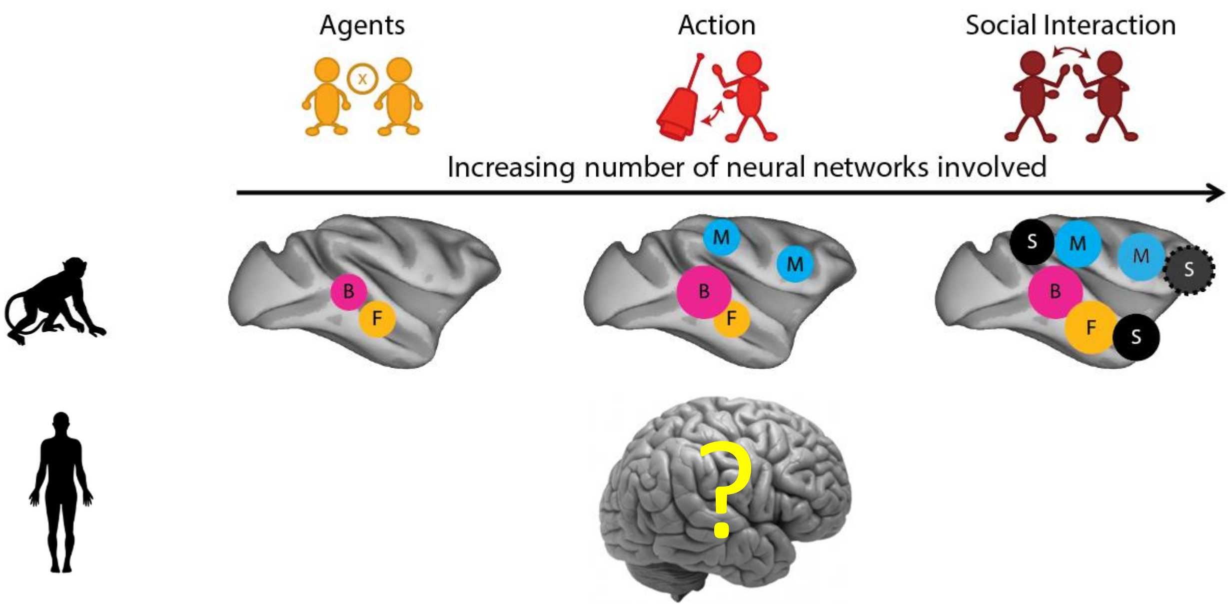
Human fMRI

with Sadie Marvel and Geena Ianni

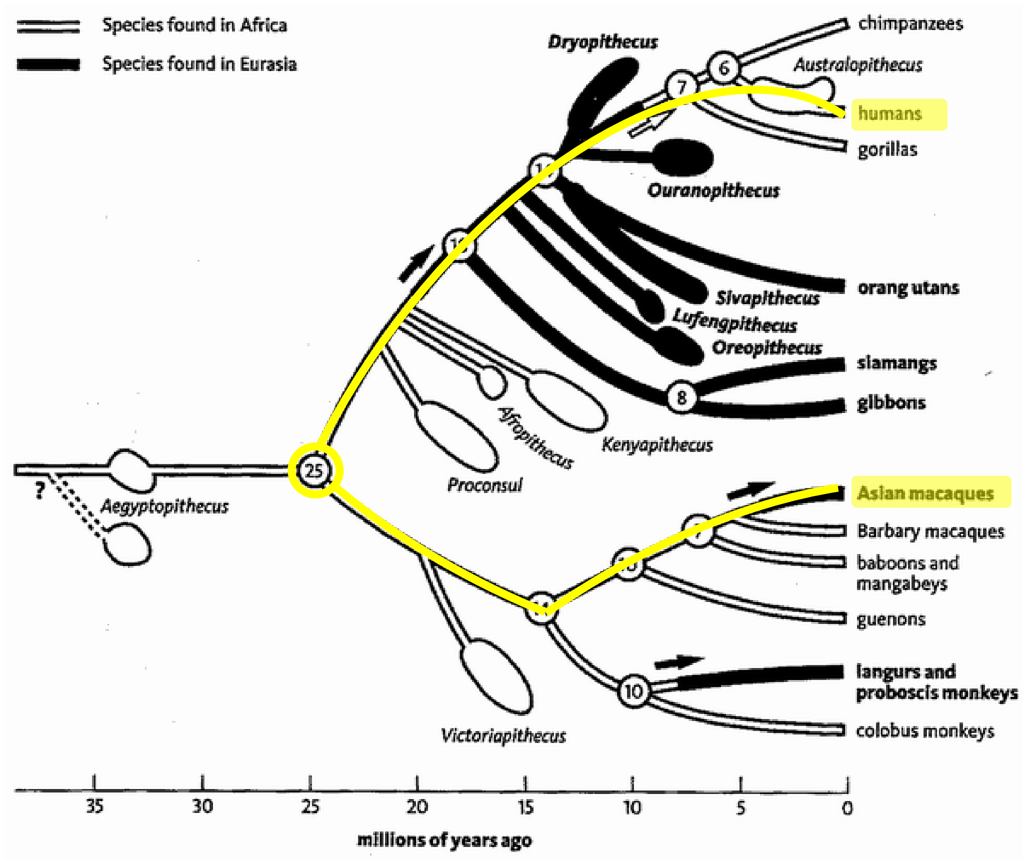
Comparing neural strategies in monkeys and humans

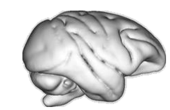
Rhesus Monkeys

Humans



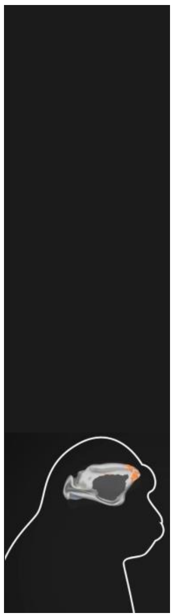
Comparing neural strategies in monkeys and humans





- Which neural strategies are shared and which ones adapted to the specific needs of the species?

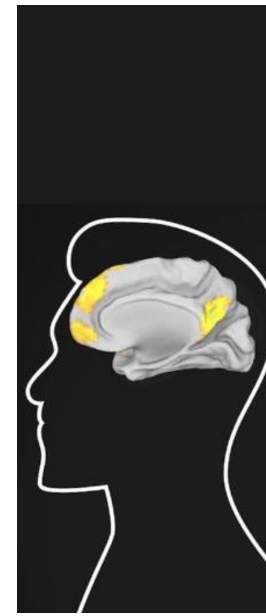
Conclusions



These results contribute to helping trace the roots of human social cognition in the primate lineage.

They provide a primate model for studying higher-level social cognition at the whole-brain scale with pharmacological manipulations and neurophysiological recordings.

Opening new venues for investigating other facets of social cognition across species.



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Shibu Antony
Marion Mallet

Postdoc and student positions available
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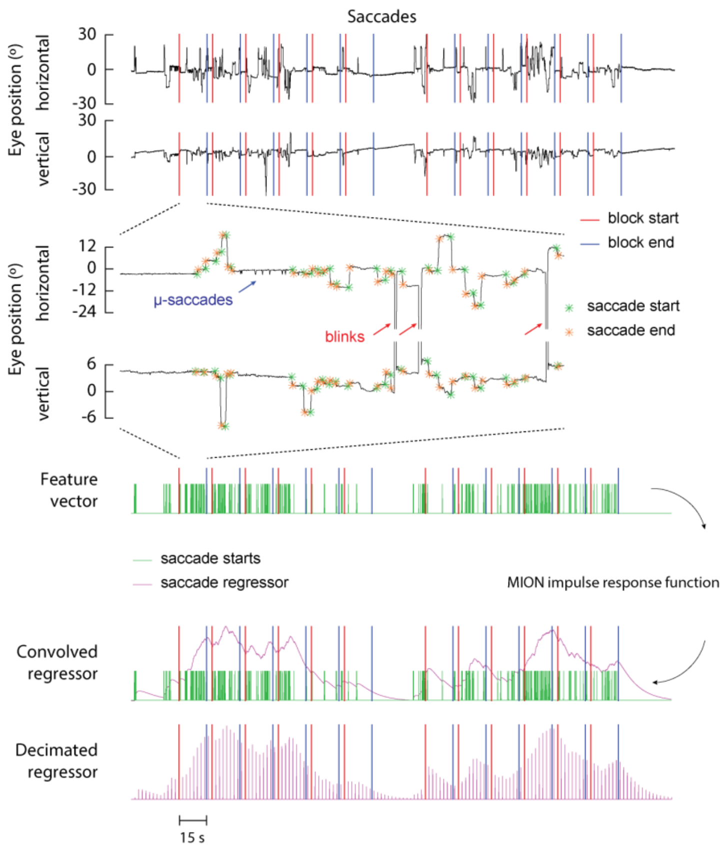
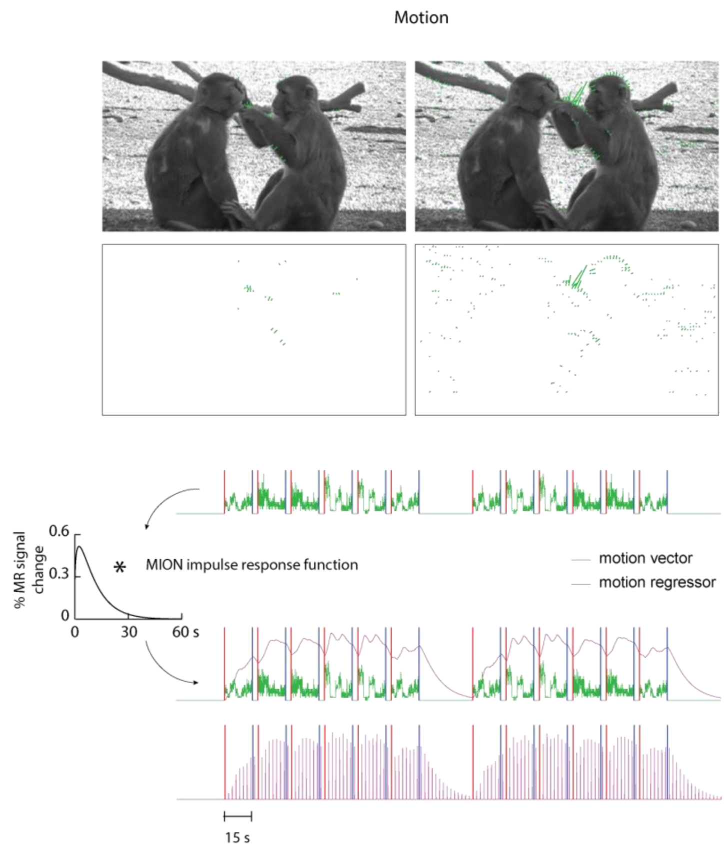
Nuisance regressors





Additional behavioral controls

Videos with a rich content, not standardized
Monkeys freely looking behavior

1. Motion
2. Luminance
3. Face velocity
4. Body velocity
5. Hands velocity
6. Object velocity
7. Pupil dilation
8. Blinks
9. Juice
10. Looking at Faces
11. Looking at Bodies
12. Looking at Hands
13. Looking at Objects
14. Gaze following
15. Emotional arousal

Additional behavioral controls