# SPATIAL COGNITION & MOTOR CONTROL

Reminders & Announcements

- Prelim 1 grades (much) later today
  - Curve will be 5 points added to everyone's grade

- Lots of extra credit opportunities!
  - SONA: https://canvas.cornell.edu/courses/74259/pages/sona-study-advertisements
  - Fritz Breithaupt
    - "The Narrative Brain", @ A.D. White House, @ 5 pm today
    - Lunch for students, @ 177 Goldwin Smith, @ 12-1:30 tomorrow

From Perception to Action
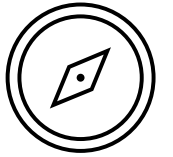
- The "How"/"Where" stream
  - Action-oriented representations
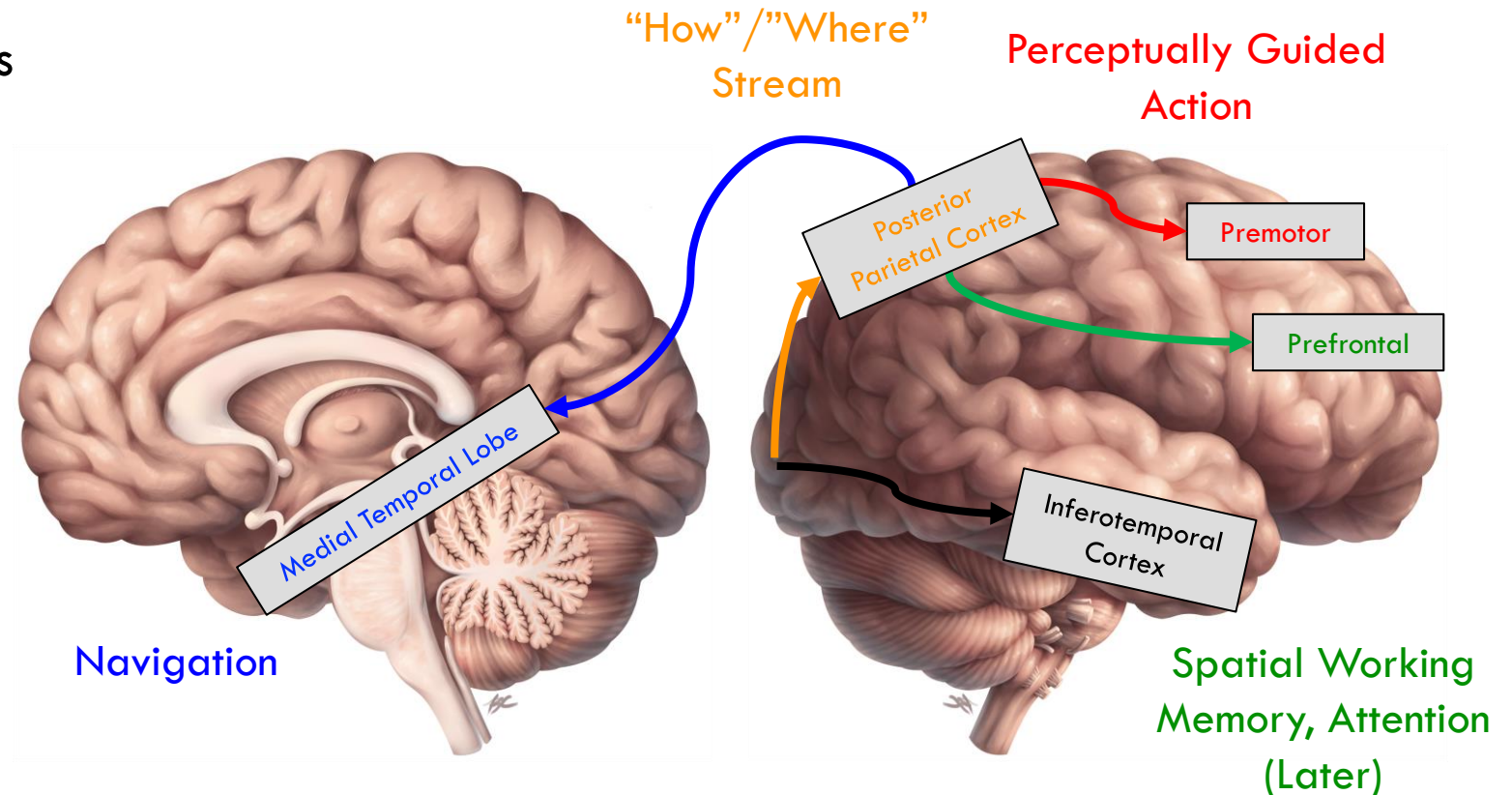 - Optic Ataxia

- Reference Frames
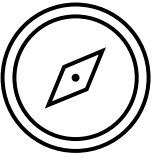 - What coordinates are used?

- Integration of…
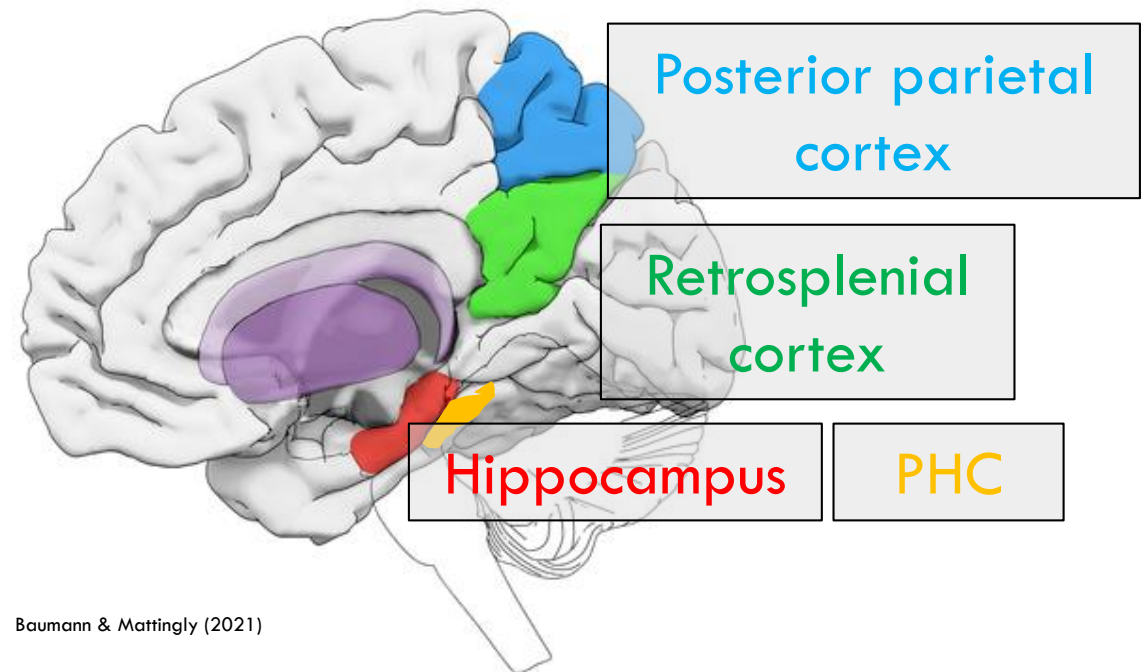 - Sensory modalities
  - Action

- Navigation

How?

- Challenge:
  - Need to code goal relative to the self; self relative to world
  - Plan and update as move through space

- Parietal to medial temporal lobe
  - Code multiple elements of space
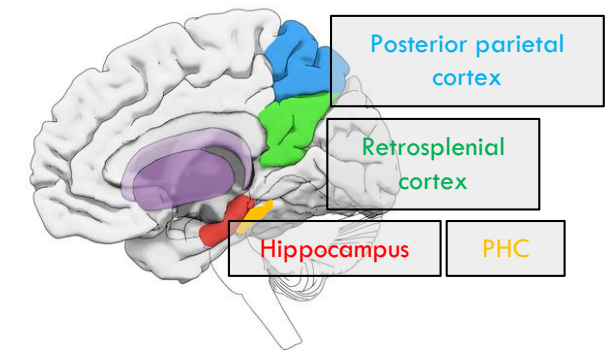 - Integrate dorsal and ventral

Posterior parietal cortex

Retrosplenial cortex

Hippocampus
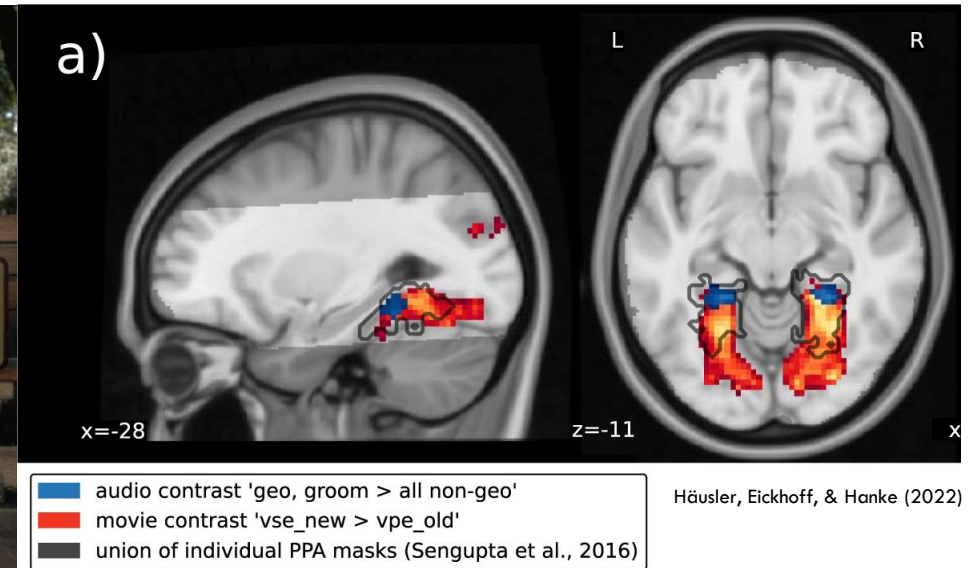
PHC

Baumann & Mattingly (2021)

Representing places

- Parahippocampal place area
  - Represents <u>specific</u> locations ("places")
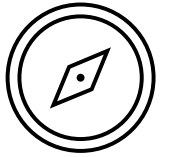 - Abstract (invariant): interior/exterior of the same location, auditory and visual places

Posterior parietal cortex

Retrosplenial cortex

Hippocampus   PHC

Penn Bookstore   1920 Commons   Freshgrocer

Exterior

Interior

Marchette, et al (2015)

a)

L   R

x=-28   z=-11   x

audio contrast 'geo, groom > all non-geo'
movie contrast 'vse_new > vpe_old'
union of individual PPA masks (Sengupta et al., 2016)

Häusler, Eickhoff, & Hanke (2022)

From Perception to Action

- The "How"/"Where" stream
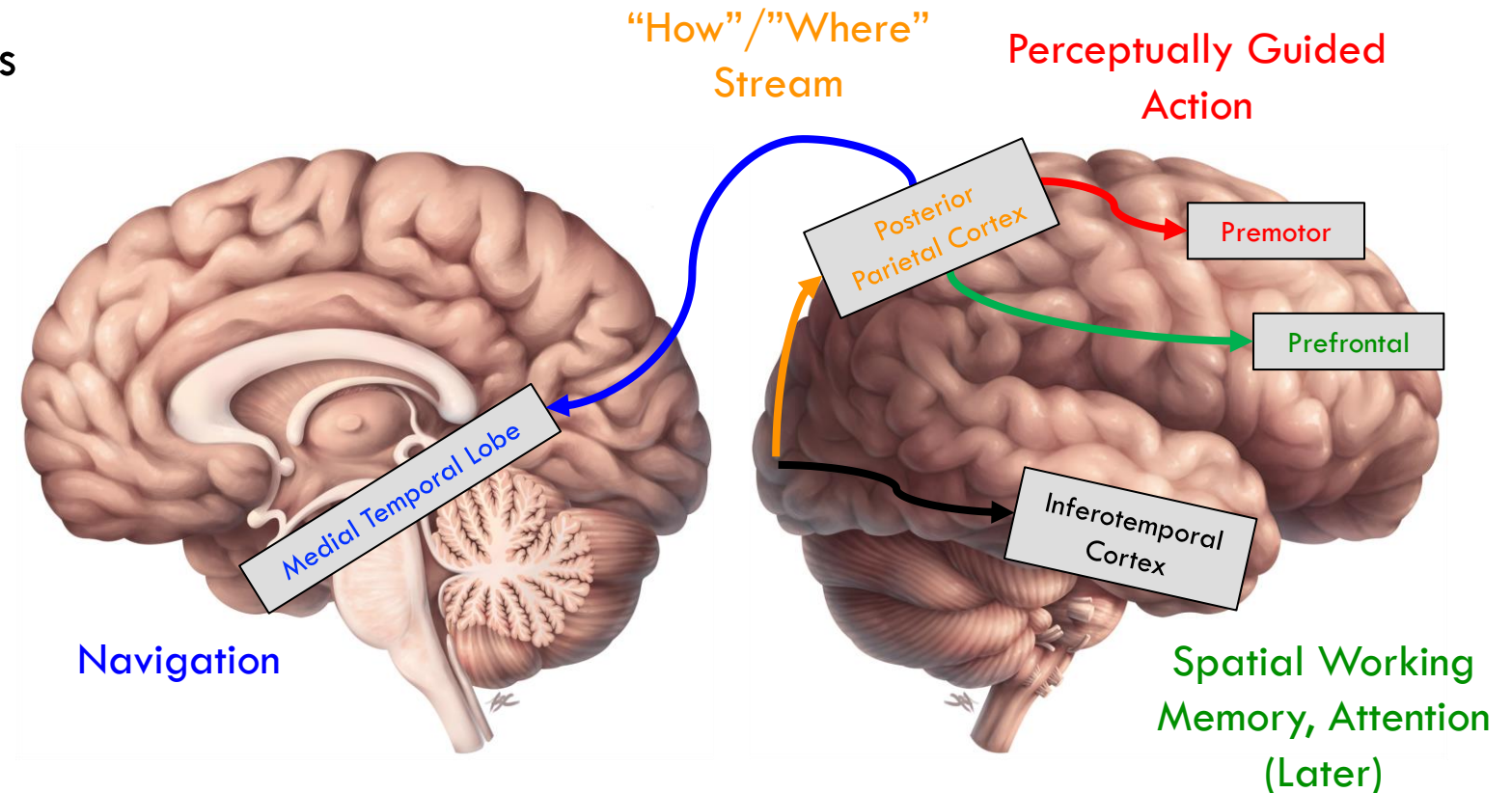 - Action-oriented representations
  - Optic Ataxia

- Reference Frames
  - What coordinates are used?

- Integration of…
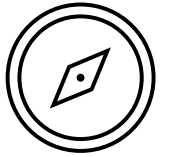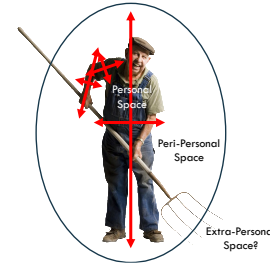 - Sensory modalities
  - Action

- Navigation

"How"/"Where" Stream

Perceptually Guided Action

Posterior Parietal Cortex

Premotor

Prefrontal

Medial Temporal Lobe

Inferotemporal Cortex

Navigation

Spatial Working Memory, Attention (Later)

How?

- **Challenge:**
  - Space & movement need to be coded relative to lots of things
  - These need to be coordinated

- **Parietal cortex**
  - Integrates information across modalities
  - Segregate representations for different effectors

Integration across modalities

# When dodging the burrito, what are some of the reference frames that you would need to keep track of?

Nobody has responded yet.

Hang tight! Responses are coming in.

Parietal cortex maps body to eye

Huang, et al. (2012)

- **Airpuffs used to map somatosensation**
  - Higher-level homunculus
  - Posterior to somatosensory strip
  - Different organization

- **Balls zoom past head to map visual field**
  - Overlaps with airpuff homunculus
  - Lower visual field -> lower body
  - Middle visual field -> shoulders and head

- **Bimodal**
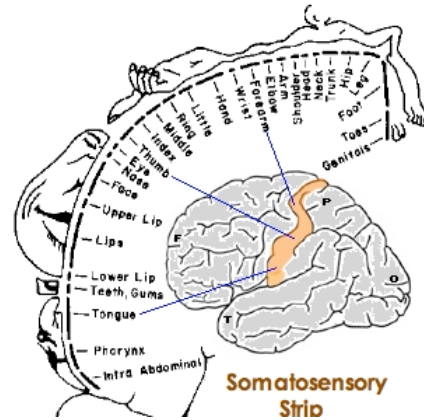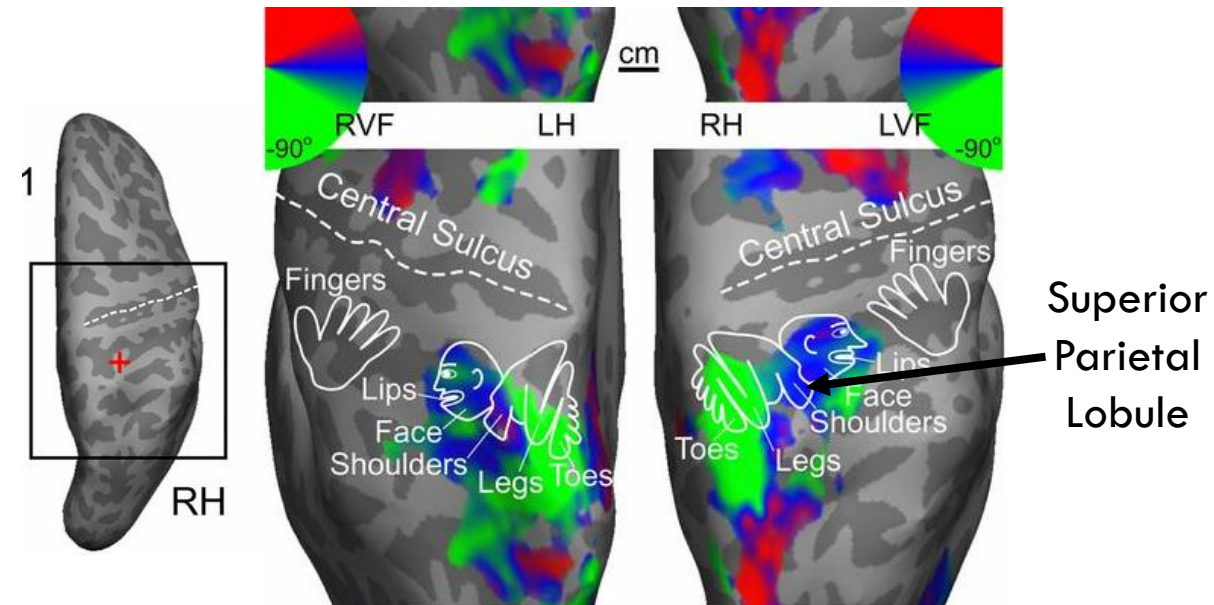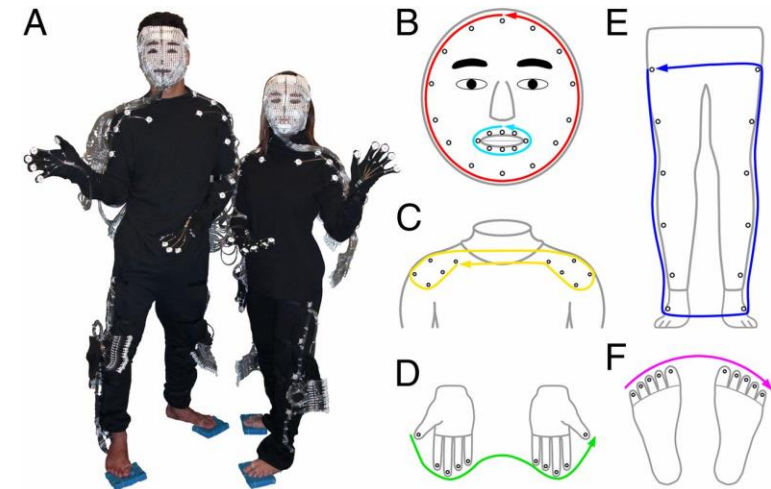
Tools change body representation

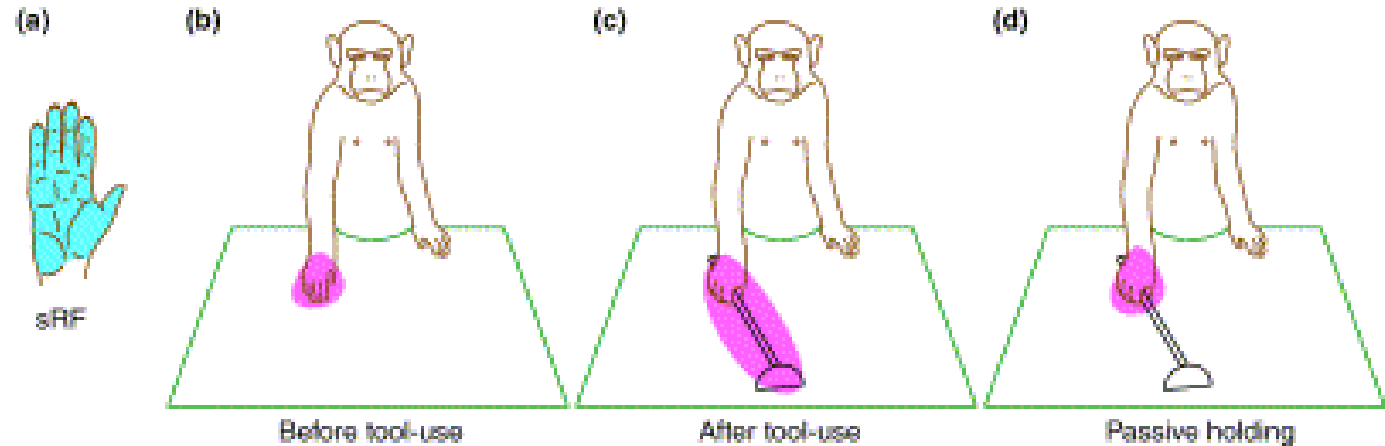- **<u>Bimodal neurons:</u>**
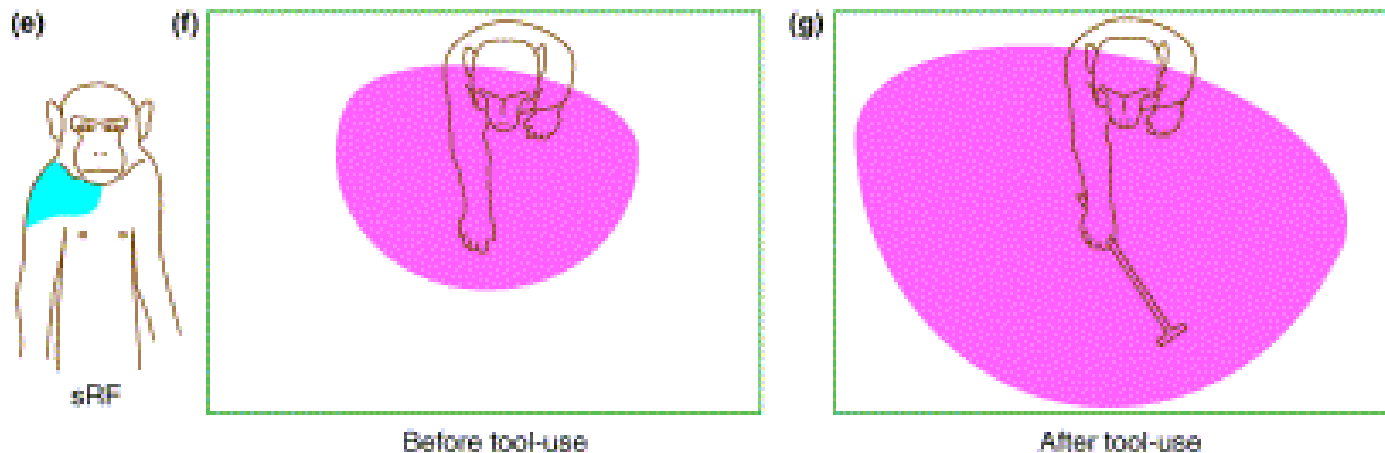 - intraparietal lobe
  - respond to vision and touch

- **Receptive field extends to**
  - actively used tool
  - reachable area
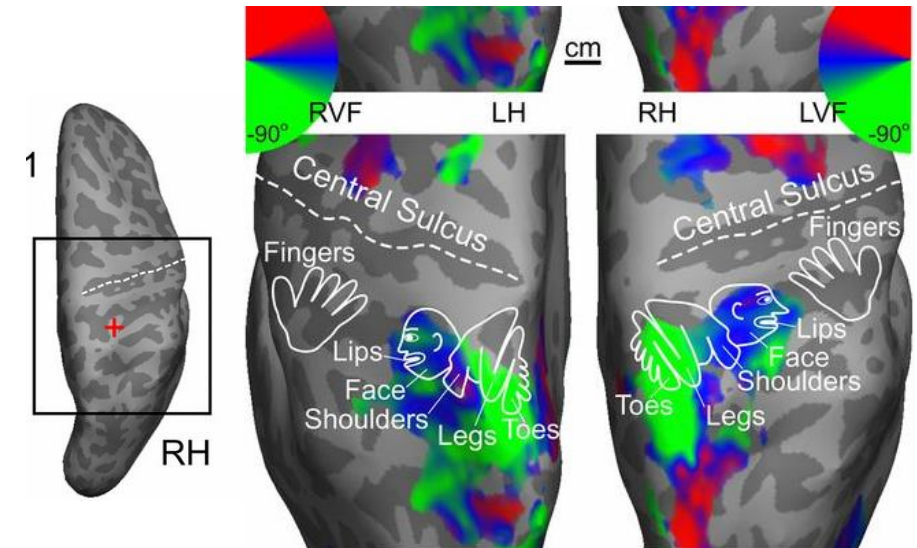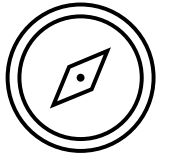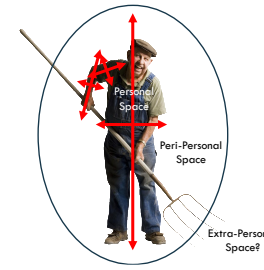

Maravita & Iriki (2004)

How?

- Challenge:
  - Space & movement need to be coded relative to lots of things
  - These need to be coordinated

- Parietal cortex
  - Integrates information across modalities
  - Segregate representations for different effectors

Touch, proprioception (e.g., where is my arm?), visual, auditory

Segregation Across Effectors

Separate representations for different movements

LIP

- LIP neurons: tuned to the direction of intended movement
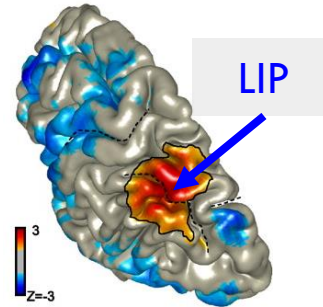
auditory delayed saccades from various fixation points

O ⊚ O 3 fixation points

⊚ ⊚ ⊚ ⊚ ⊚ 5 speakers

HEAD-centered
Neuron

EYE-centered
Neuron
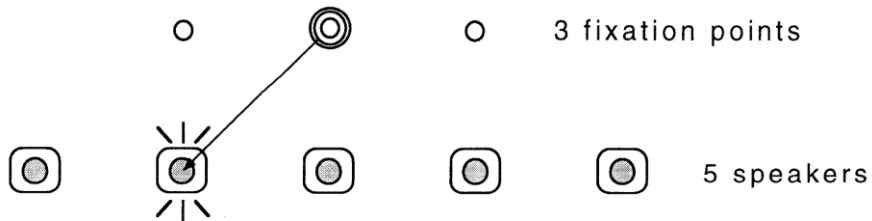
Different lines: eyes start pointing left, right, and ahead, relative to head

B 16

firing rate (Hz)

8

0

-24 -12 0 12 24

24

12

0

-24 -12 0 12 24
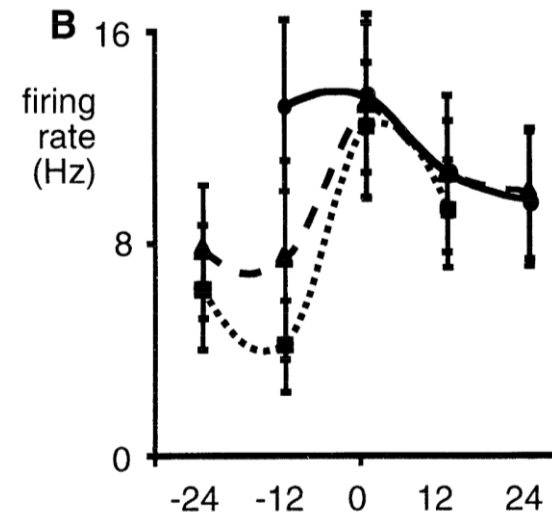
Direction relative to HEAD   Direction relative to EYE
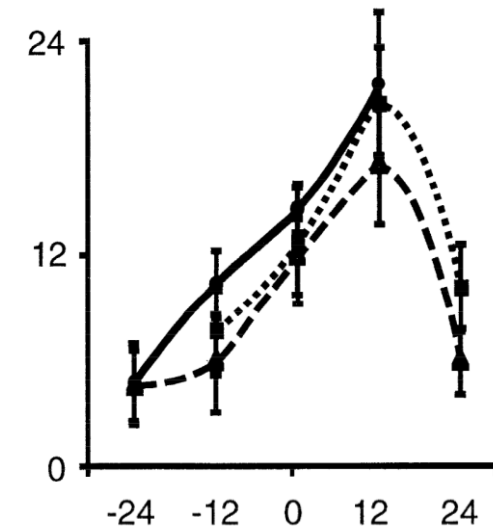
- Some relative to head; Some relative to eye

Stricanne et al (1996)

Segregate by effector (what's moved)

- Different regions for different types of movement
  - Eyes (Saccades): Lateral intraparietal area
  - Arm (Reach): Parietal reach region
  - Hand (Grasp): Anterior intraparietal area

- Project to frontal regions involved in
  - motor planning
  - moving that effector

Parietal **Reach** Region

Lateral intraparietal area (area LIP)
Saccade

Anterior intraparietal area (area AIP)
Grasp
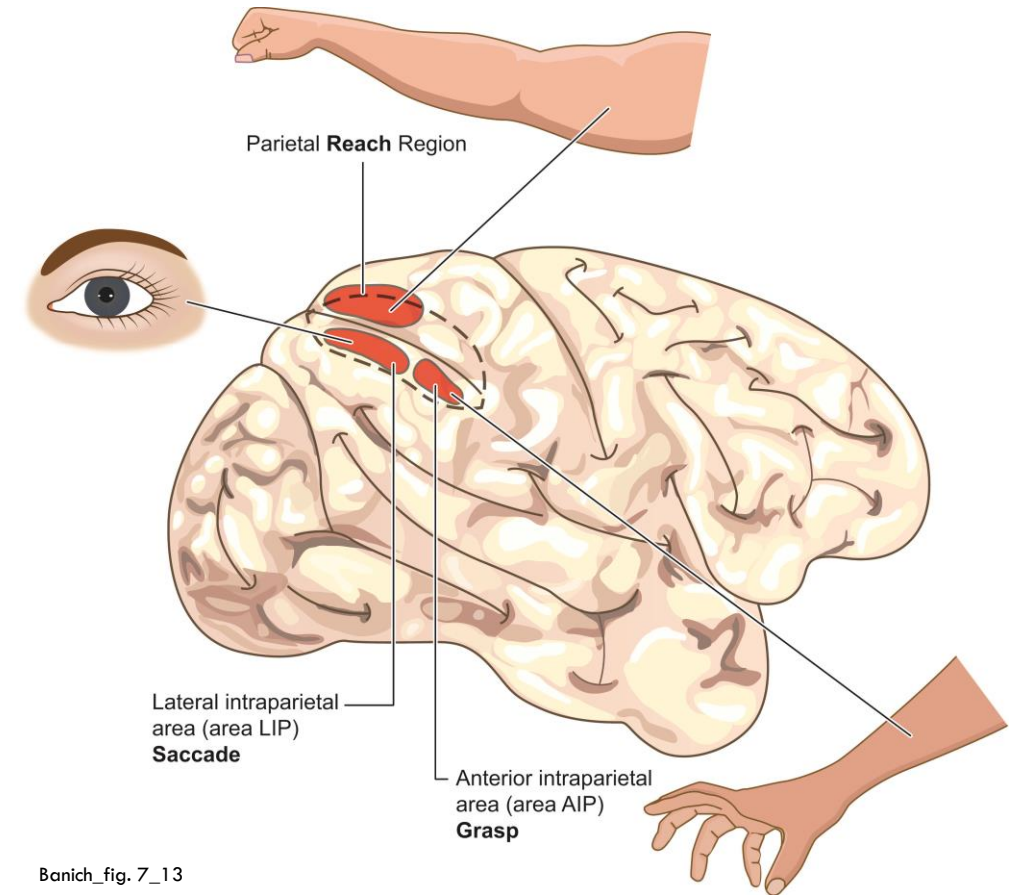
Banich_fig. 7_13

Take-aways (Vision for Action & Spatial Processing)

- Perception can guide action

  - How/What pathway (Tectopulvinar as well)

- Posterior parietal cortex

  - Coordinate across multiple egocentric reference frames

  - Integrates body sense with visual processing

  - Segregates based on effector

- Navigation

  - Multiple aspects of allocentric representations (place, direction)

  - Retrosplenial cortex may mediate between allo- and egocentric frames

Is V1 essential for visual perception?

- Blindsight
  - Patient TN
  - Bilateral scotoma

- How?

- Not all visual processing goes through V1

Tectopulvinar Pathway

Parietal Eye Fields

Frontal Eye Fields

Pulvinar

Motion Sensitive Area MT

Superior Colliculus
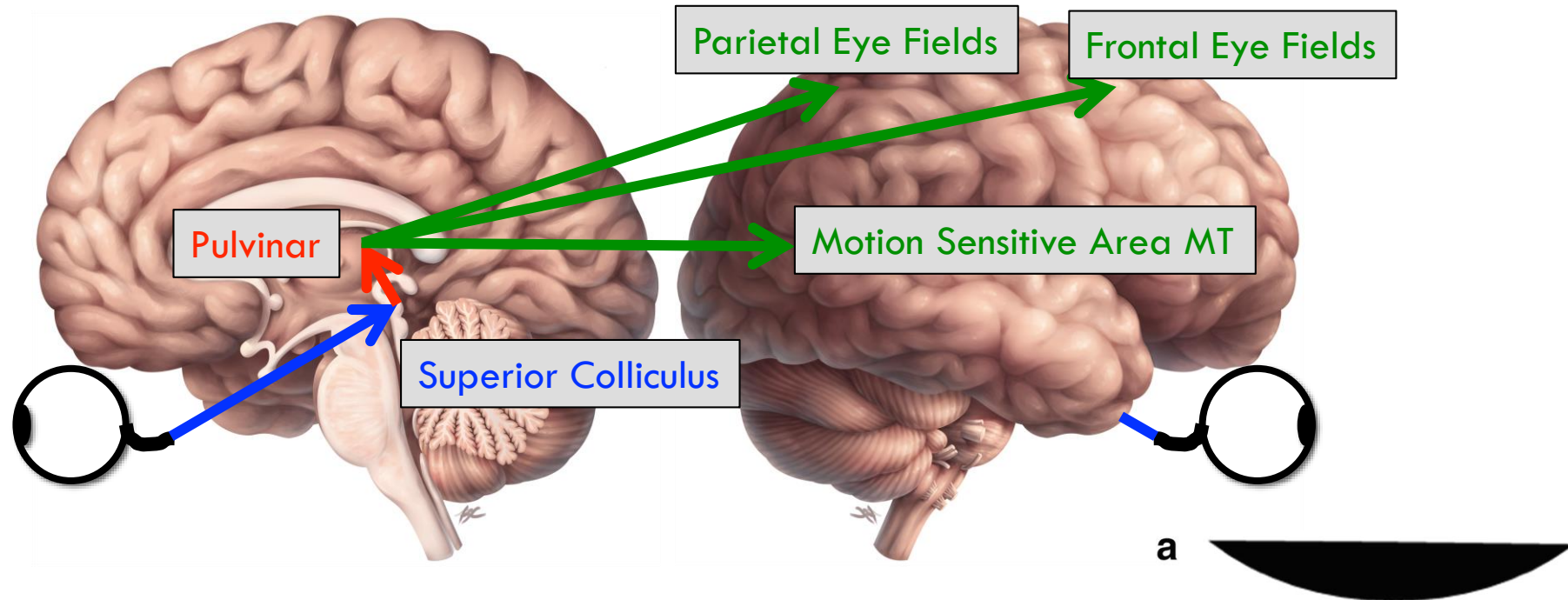
- **Important for orienting eyes/head to stimuli**
  - Motion sensitive, fast, multi-modal (integrates auditory info)
  - Bypasses primary visual cortex
  - Evolutionarily old (superior colliculus is part of the tectum)
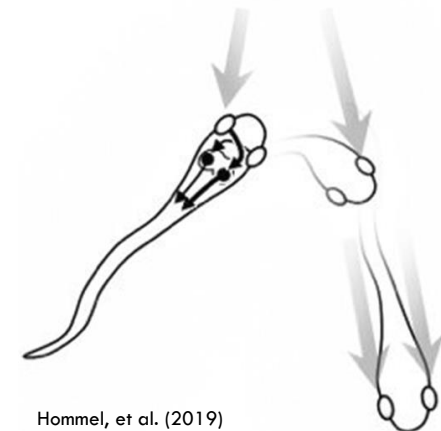
Hommel, et al. (2019)

A perception problem

- How do we know where a sound is coming from?

Interaural Time Difference: Sound reaches ears at different times

https://www.pa.msu.edu/acoustics/woodworth.pdf

Think back to several weeks ago. Which of the following increases the likelihood that a neuron to generate a new action potential?

It receives inhibitory inputs at a slow and steady rate

It receives excitatory inputs that at a slow and steady rate

It receives multiple excitatory inputs at about the same time

It is already in the process of generating an action potential

Think back to several weeks ago. Which of the following increases the likelihood that a neuron to generate a new action potential?

0

It receives inhibitory inputs at a slow and steady rate

0%

It receives excitatory inputs that at a slow and steady rate

0%

It receives multiple excitatory inputs at about the same time

0%

It is already in the process of generating an action potential

0%

Think back to several weeks ago. Which of the following increases the likelihood that a neuron to generate a new action potential?

✓ 0

It receives inhibitory inputs at a slow and steady rate

0%

It receives excitatory inputs that at a slow and steady rate

0%

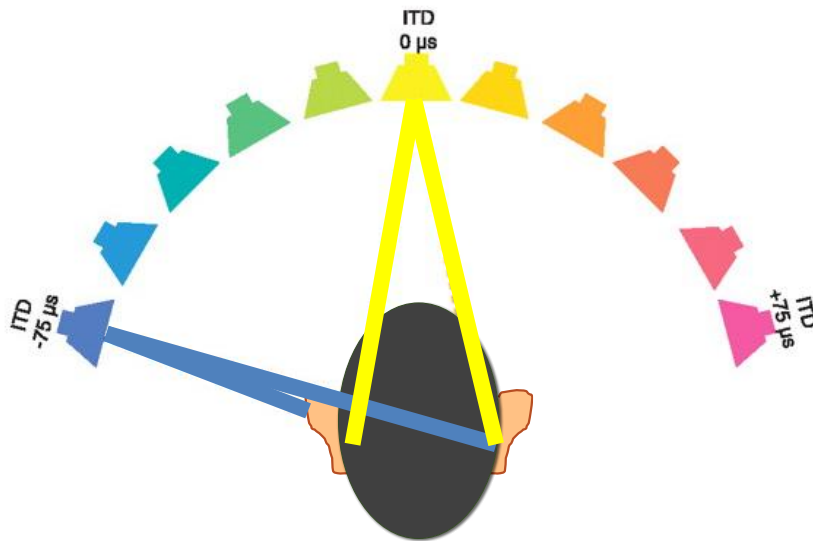It receives multiple excitatory inputs at about the same time

0%

It is already in the process of generating an action potential

0%

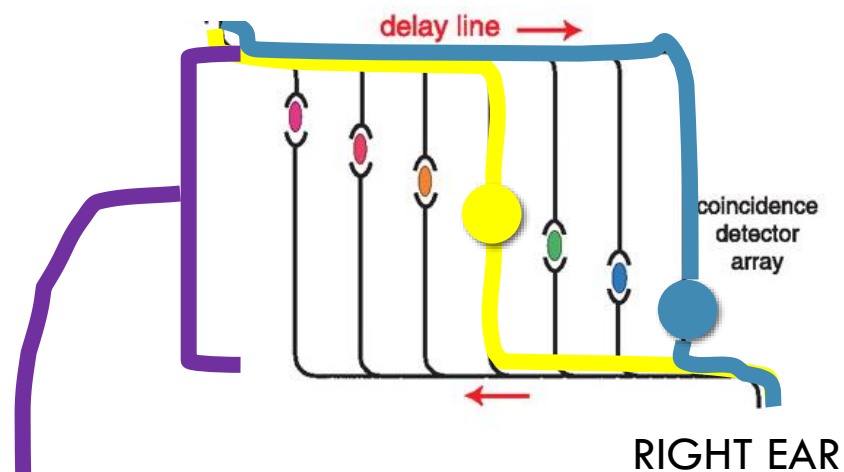# How do we know where a sound is coming from?

Interaural Time Difference

Solution exploits the physical properties of sounds, our heads, and how neurons work.

Timing and physical structure matter.

Coincidence Detectors
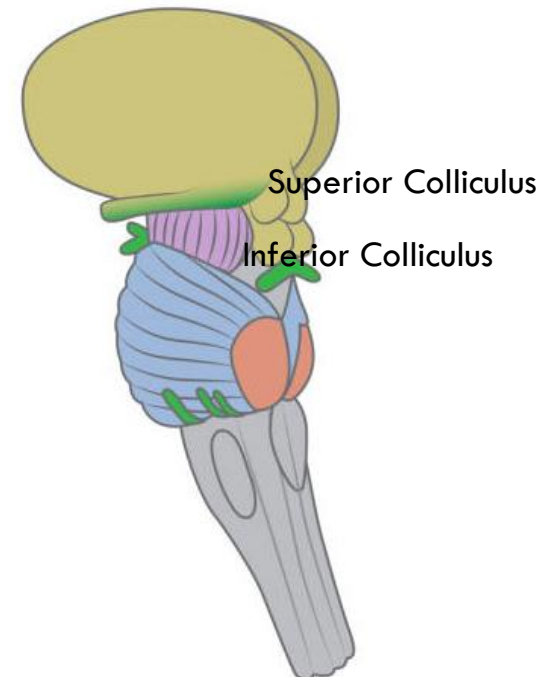
Superior Olivary Nucleus in Brainstem

RIGHT EAR

Fire if input from left and right arrives at the same time.

Map of horizontal location

Output goes to Inferior Colliculus, then Superior Colliculus

Brainstem

Superior Colliculus

Inferior Colliculus

Take-aways (Tectopulvinar Pathway)

- Alternative pathway from eye to cortex
  - Superior colliculus -> pulvinar (thalamus) -> cortex

- Very fast, sensitive to motion

- Projects to areas involved in movement
  - Older circuits may have more direct effect

- One way auditory info may be incorporated

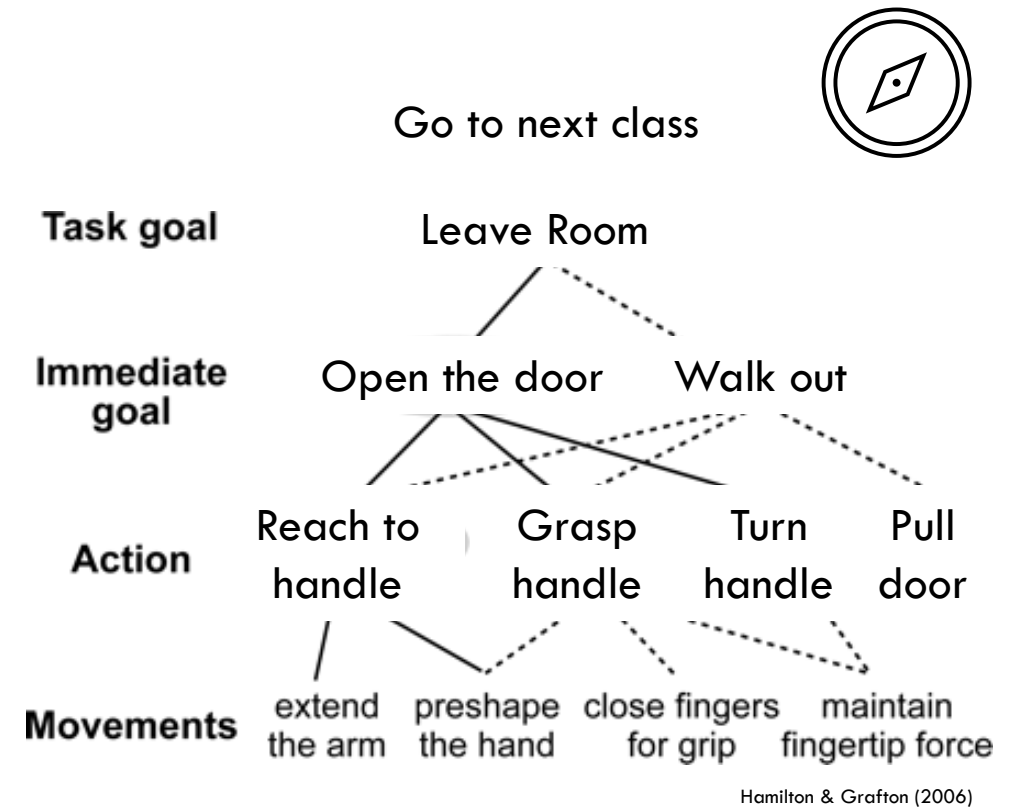- May help localize things in space and guide movement

How do you open the door?

How do you dodge the burrito?

The Plan

- **How movements are generated**
  - Motor plan
  - Posterior parietal cortex to muscles

- **Selection and evaluation of movement**
  - Basal ganglia
  - Cerebellum
  - Anterior cingulate, right inferior frontal cortex

- **Movement disorders**
  - Parkinson's Disease
  - Huntington's Disease

Go to next class

Task goal	Leave Room
Immediate goal	Open the door Walk out
Action	Reach to handle Grasp handle Turn handle Pull door
Movements	extend the arm preshape the hand close fingers for grip maintain fingertip force

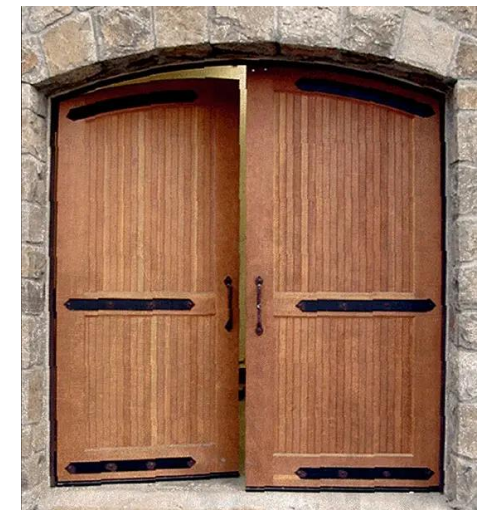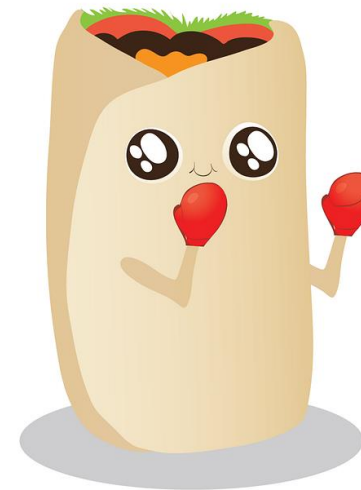Hamilton & Grafton (2006)
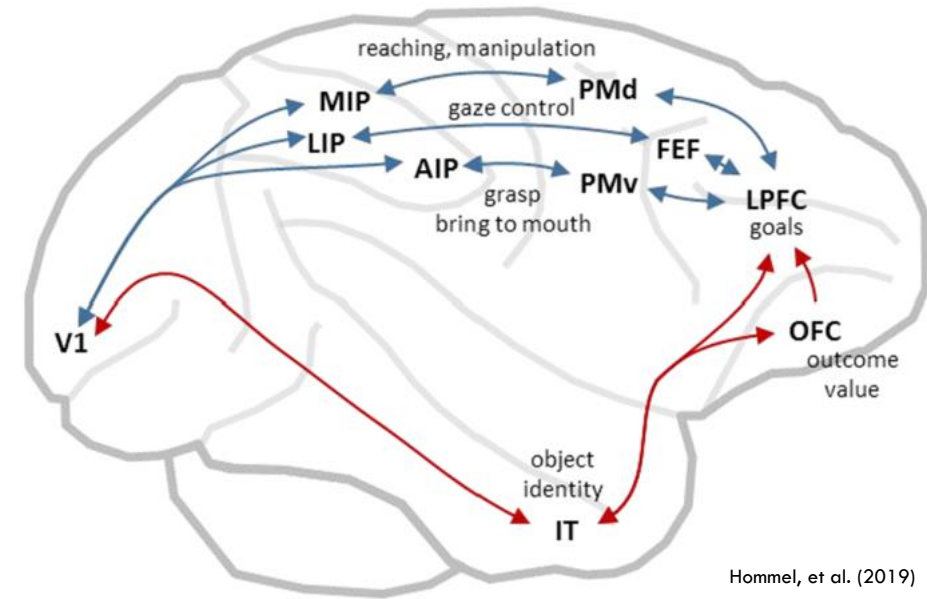
Major Structures and Functions

The Basic Process

A model of the movement goal

- Posterior parietal cortex
  - Action oriented representations

- Where body and things in the world are in relation to each other
  - Where to move eyes, hand
  - How to shape grip
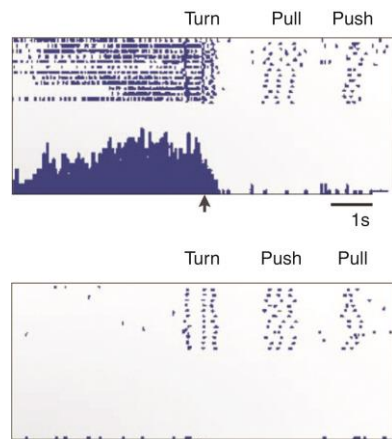 - Update if/as sensory information changes (e.g., if the door moves)

Hommel, et al. (2019)

Sequencing movements

- **Supplementary Motor Complex**
  - Planning movements
  - Codes learned sequence of movements
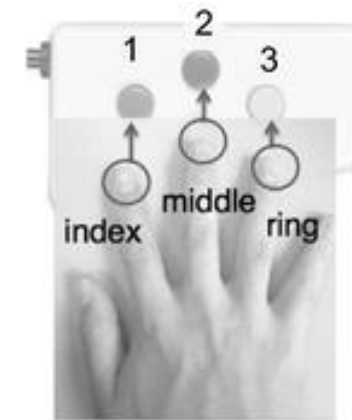 - Bilateral, precedes movement

fMRI Decoding: Patterns of activity differ for the two sequences

Nambu, et al (2015)

Specific to Sequence

Specific to Position in Sequence

Banich_fig. 4_18
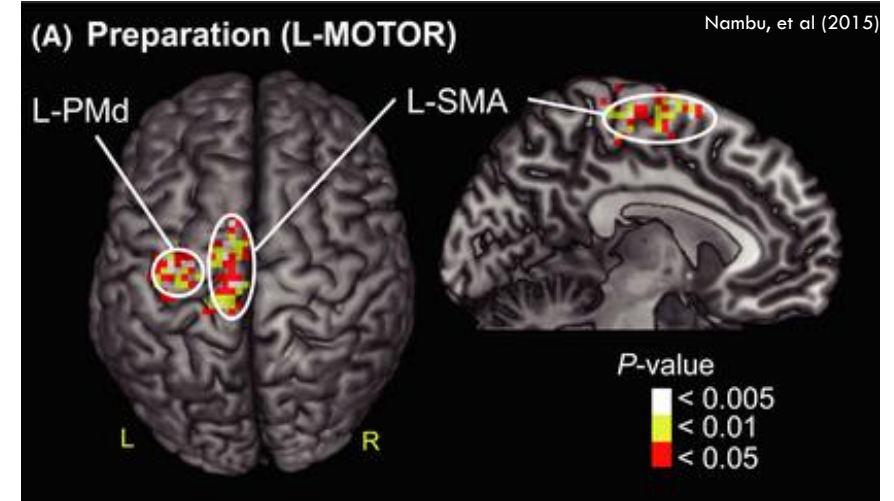
Integrating motor commands with sensory info

- Premotor selects and modifies movements

- PMd: select based on sensory information
  - Voluntary actions to locations
  - Frontal eye field

- PMv: adjust as manipulating
  - Shaping hand for grasping
  - Mirror neurons

Based on what you just learned, which of the following correctly maps area to information coded?

Posterior Parietal Cortex (PPC) : Position of action in a sequence

Supplementary Motor Complex (SMC) : Changes in sensory input

Dorsal Premotor Cortex (PMd) : The entire motor sequence

Ventral Premotor Cortex (PMv) : Grip

Based on what you just learned, which of the following correctly maps area to information coded?

Posterior Parietal Cortex (PPC) : Position of action in a sequence

0%

Supplementary Motor Complex (SMC) : Changes in sensory input

0%

Dorsal Premotor Cortex (PMd) : The entire motor sequence

0%

Ventral Premotor Cortex (PMv) : Grip

0%

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0%

Supplementary Motor Complex (SMC) : Changes in sensory input

0%

Dorsal Premotor Cortex (PMd) : The entire motor sequence

0%

Ventral Premotor Cortex (PMv) : Grip

0%