A New Neural Framework for Visuospatial Processing

Dwight J. Kravitz, Kadharbatcha S. Saleem, Chris I. Baker and Mortimer Mishkin

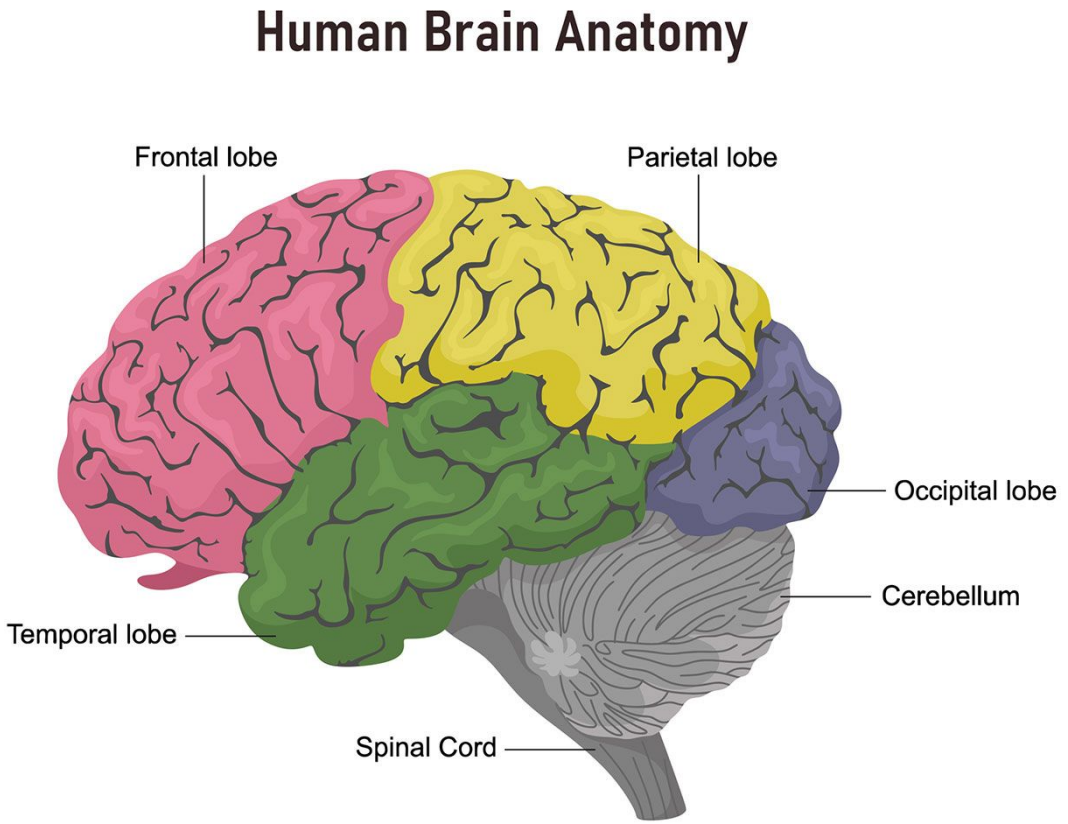
Presented by: Shrey Sahgal & Benjamin Steinig

Agenda

- Background: Brain Anatomy
- Evolution of Visuospatial Processing Theories
- A New Neural Framework
- Analogies in Robotics

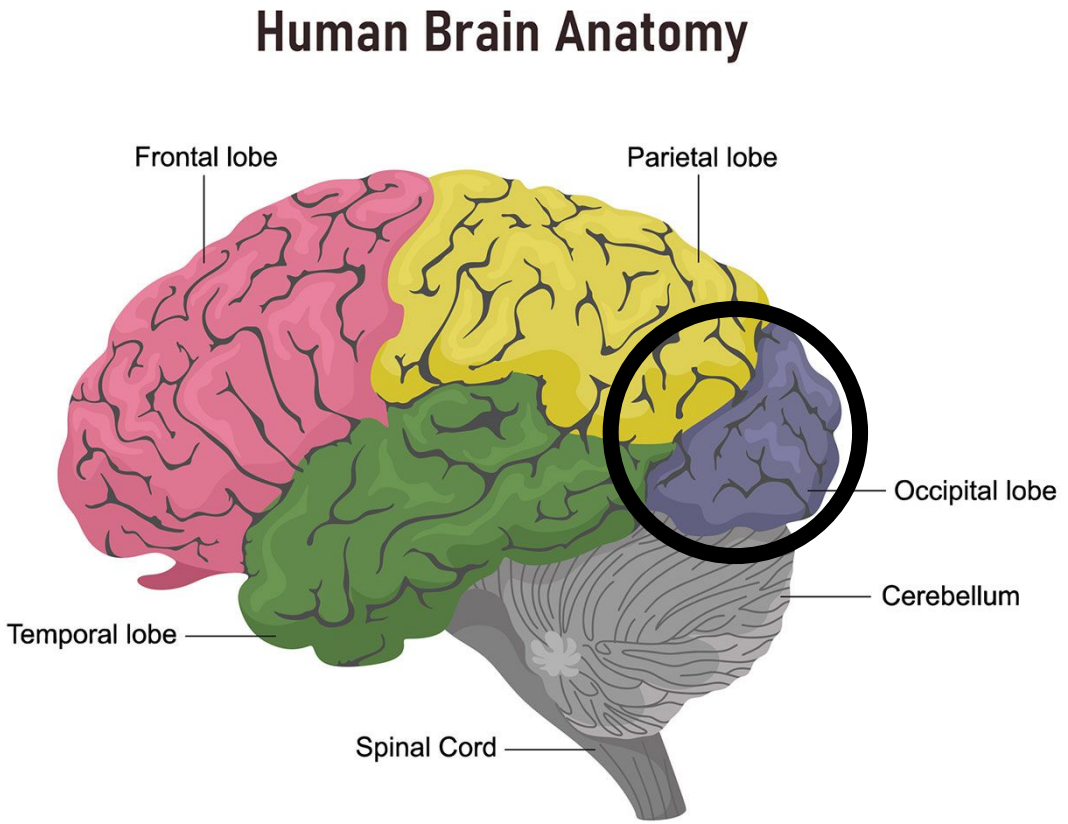
Background

- Occipital lobe: visual processing
- Parietal lobe: integrate sensory input
- Prefrontal cortex: regulating thoughts, actions and emotions
- Premotor cortex: guiding movement of the limbs
- Medial temporal lobe: episodic and spatial memory



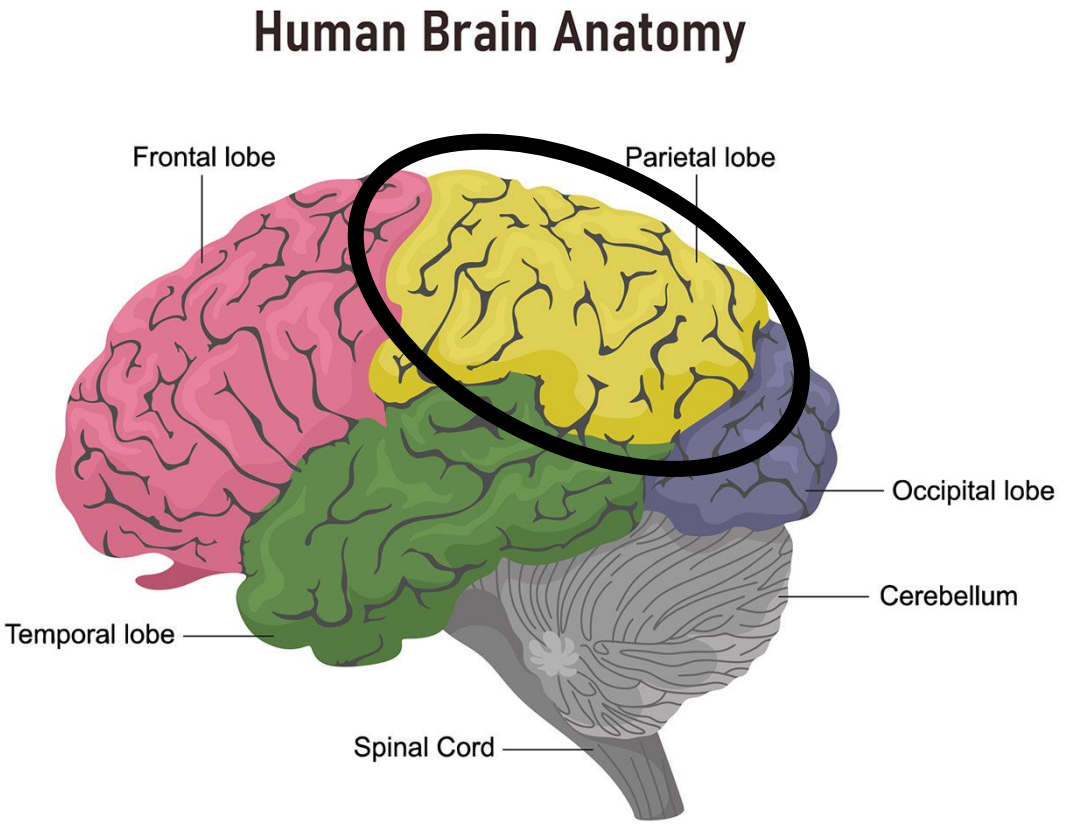
Background

- **Occipital lobe**: visual processing
- Parietal lobe: integrate sensory input
- Prefrontal cortex: regulating thoughts, actions and emotions
- Premotor cortex: guiding movement of the limbs
- Medial temporal lobe: episodic and spatial memory



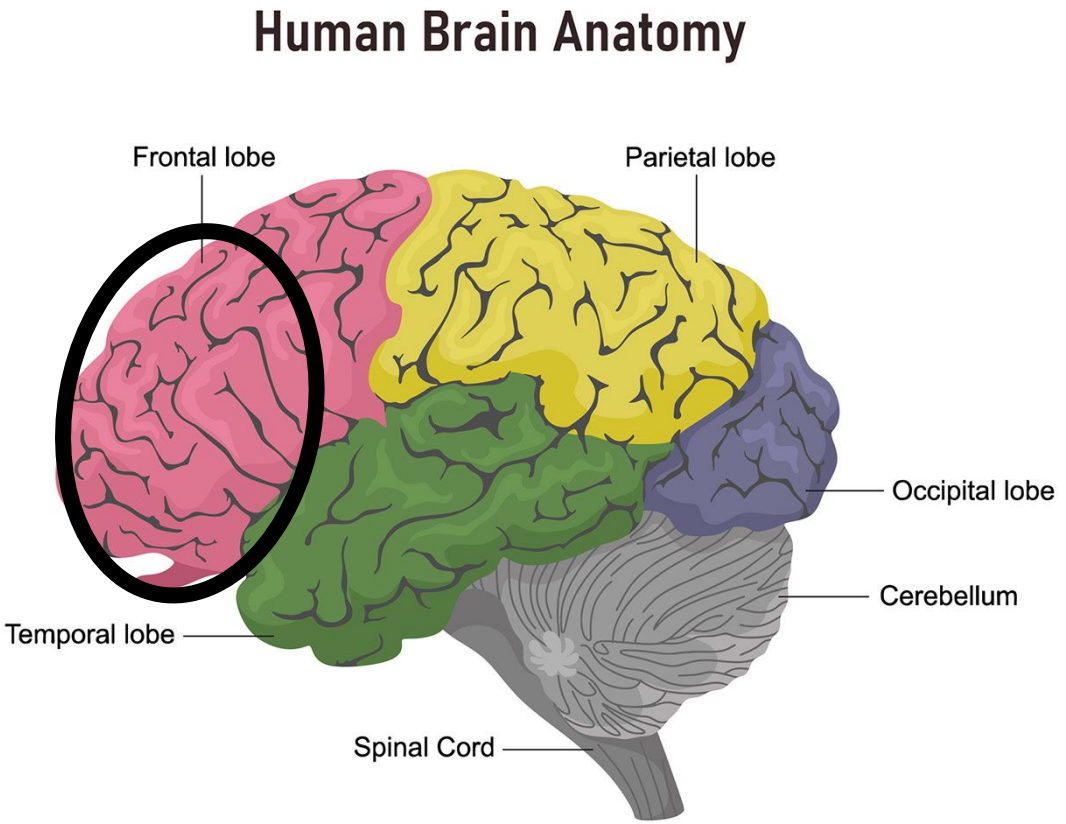
Background

- Occipital lobe: visual processing
- **Parietal lobe**: integrate sensory input
- Prefrontal cortex: regulating thoughts, actions and emotions
- Premotor cortex: guiding movement of the limbs
- Medial temporal lobe: episodic and spatial memory



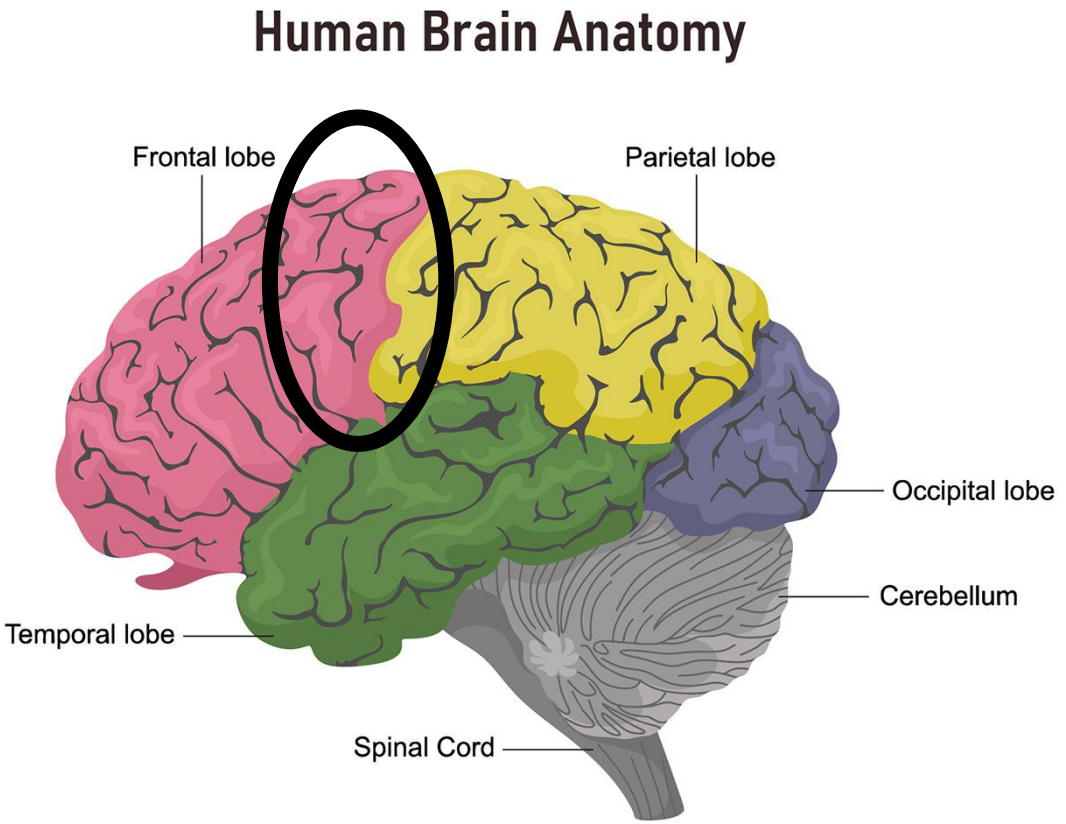
Background

- Occipital lobe: visual processing
- Parietal lobe: integrate sensory input
- **Prefrontal cortex**: regulating thoughts, actions and emotions
- Premotor cortex: guiding movement of the limbs
- Medial temporal lobe: episodic and spatial memory



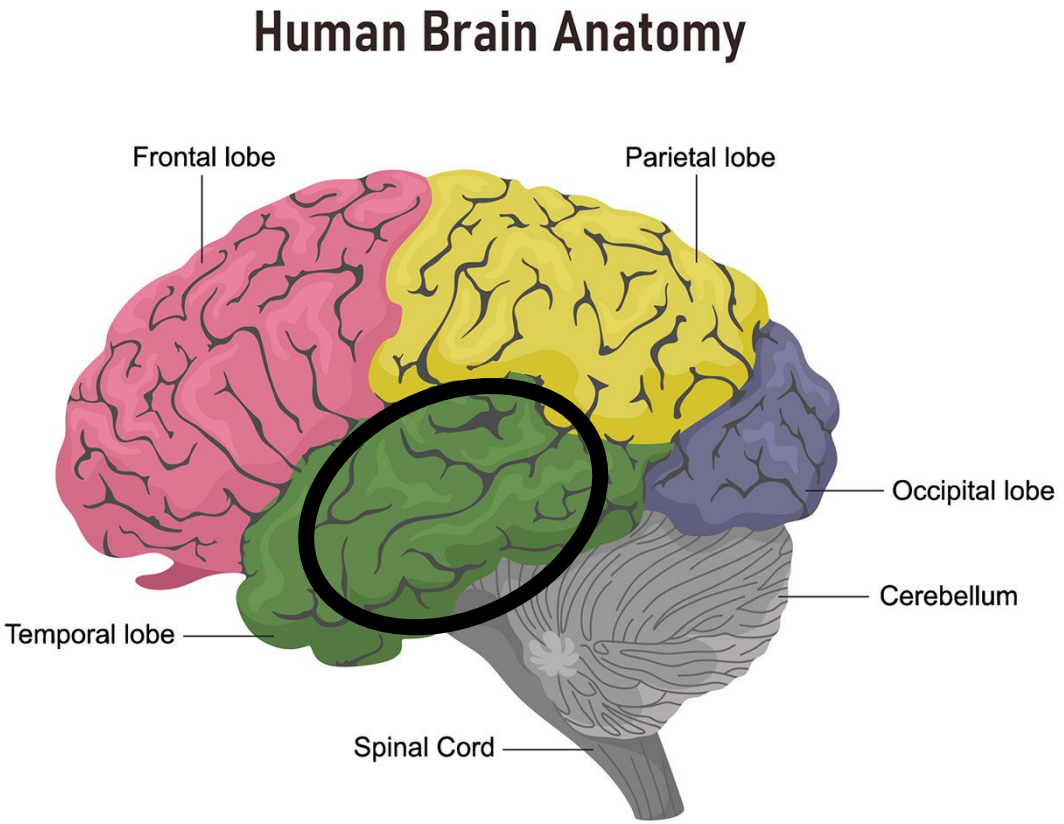
Background

- Occipital lobe: visual processing
- Parietal lobe: integrate sensory input
- Prefrontal cortex: regulating thoughts, actions and emotions
- **Premotor cortex**: guiding movement of the limbs
- Medial temporal lobe: episodic and spatial memory

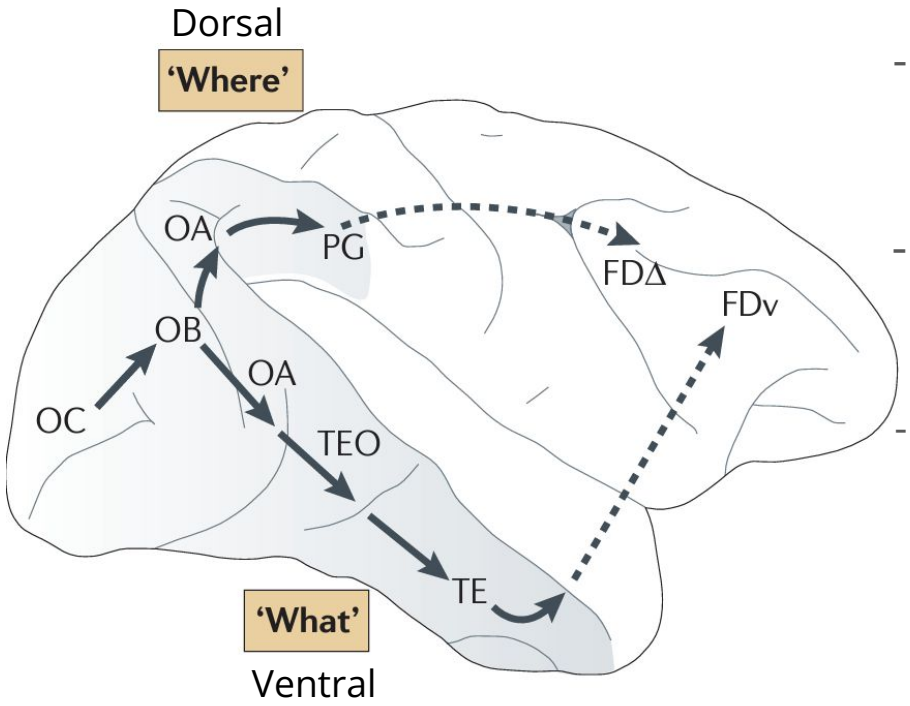


Background

- Occipital lobe: visual processing
- Parietal lobe: integrate sensory input
- Prefrontal cortex: regulating thoughts, actions and emotions
- Premotor cortex: guiding movement of the limbs
- **Medial temporal lobe**: episodic and spatial memory

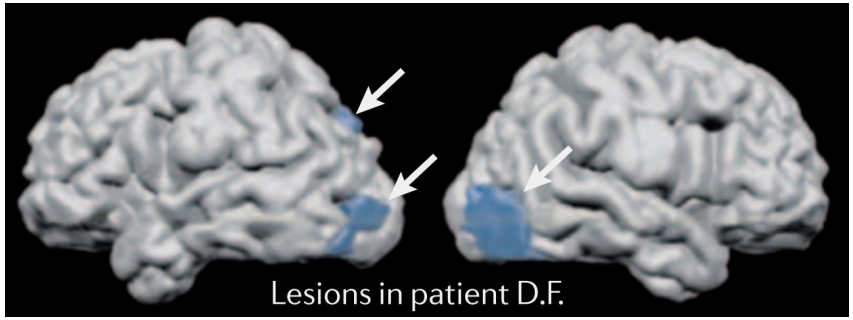


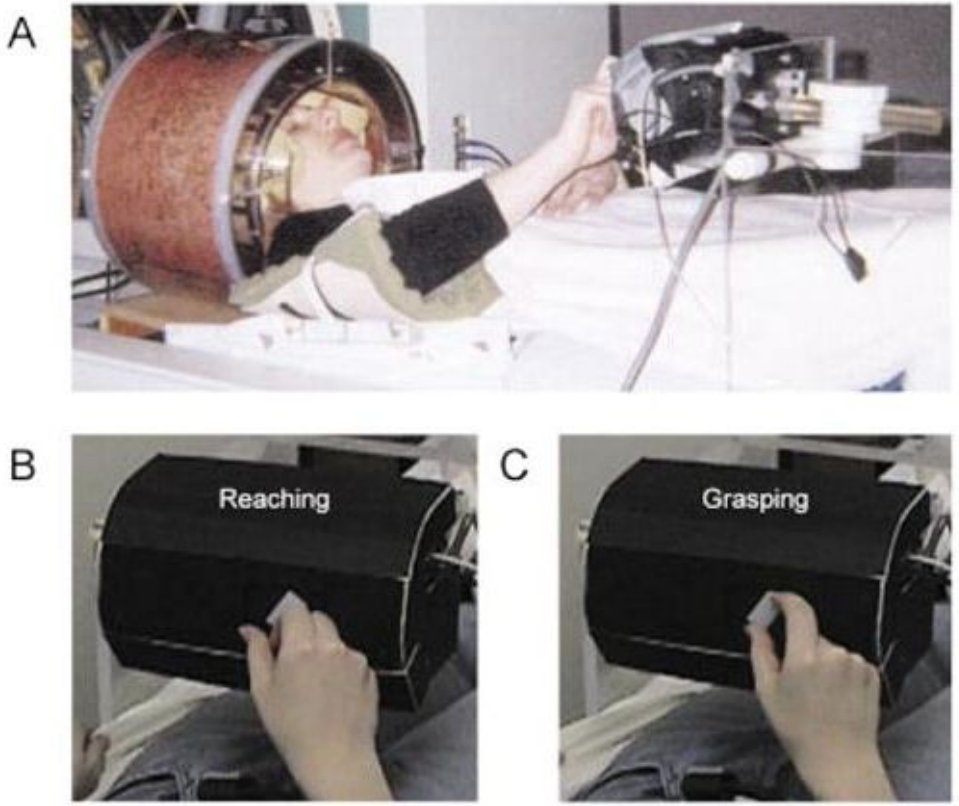
Frameworks for Visuospatial Processing - Original (1982)



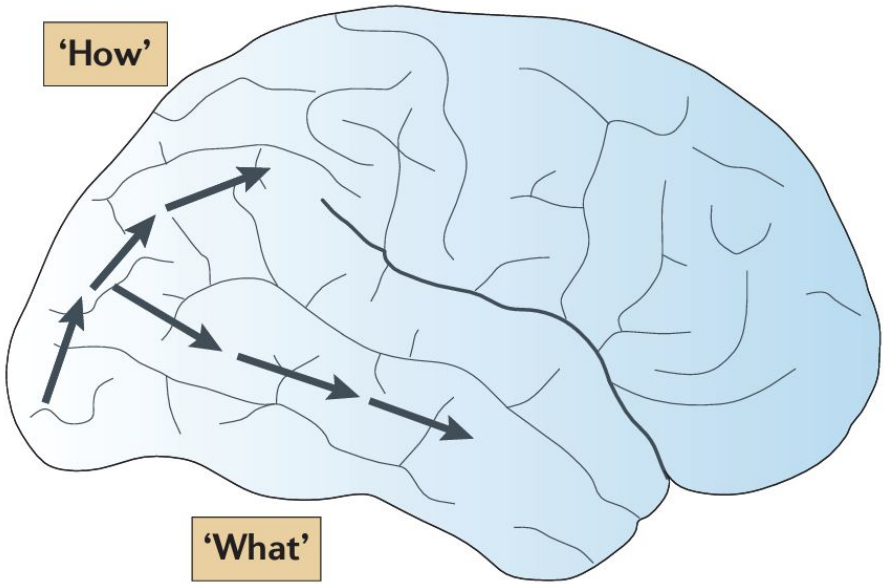
- Original framework describing the division of visual processing into Dorsal and Ventral streams
- Ventral stream ("vision for perception"): mainly concerned with recognition and discrimination of objects
- Dorsal stream ("vision for action"): mainly concerned with visually guided reaching and grasping.

Patient D.F. & the redefinition of the Dorsal stream





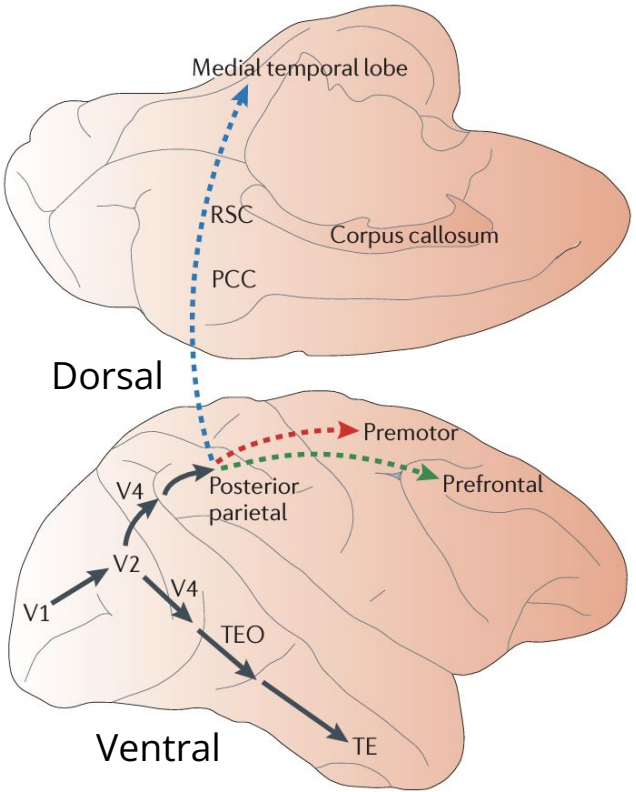
Frameworks for Visuospatial Processing - Redefined (2003)



- Recharacterization of the dorsal stream as the “how” of visuospatial processing

- Dorsal stream capable of producing representations to both conscious and unconscious processing.

Frameworks for Visuospatial Processing - New (2011)



- New framework reflects advances in understanding of the anatomical connections in the dorsal stream

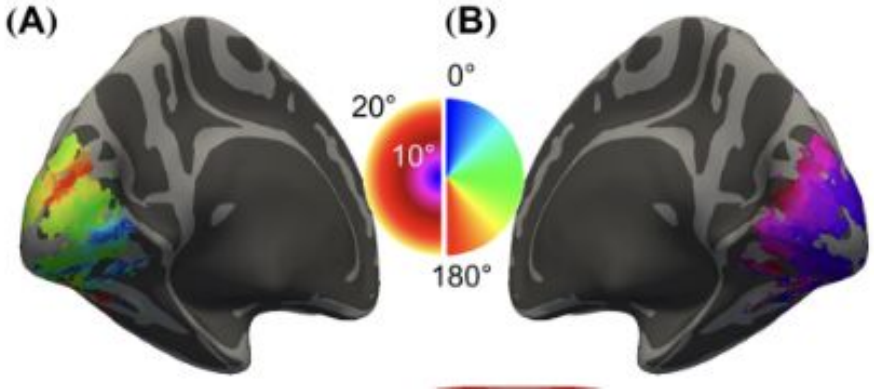
- The dorsal stream is made up of three pathways which handle different processing tasks

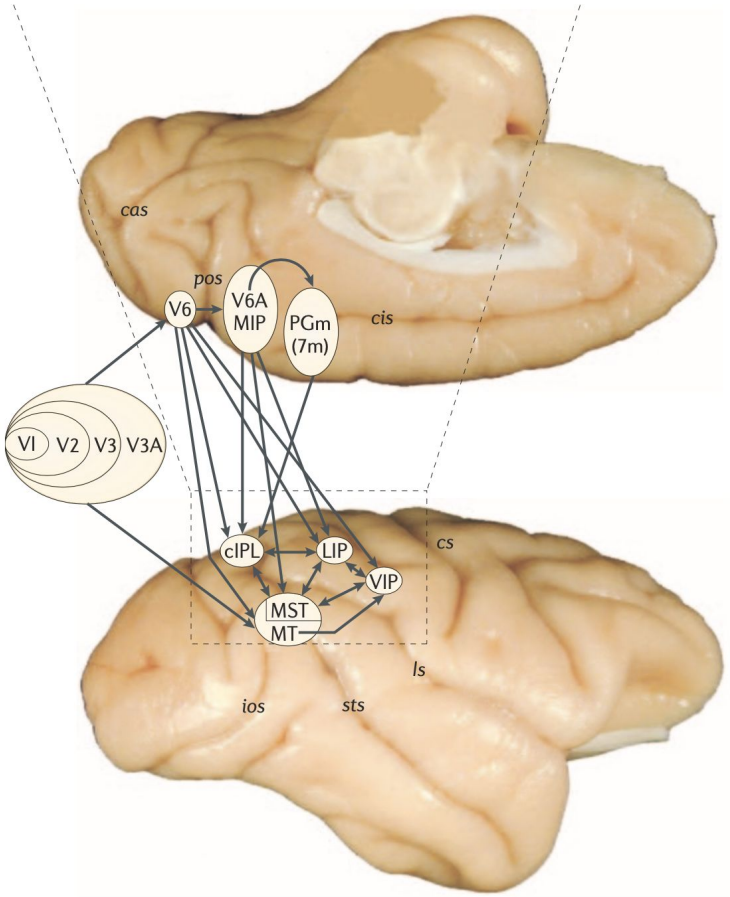
A New Framework for Visuospatial Processing

- Parieto-prefrontal
  - Spatial working memory
- Parieto-premotor
  - Visually guided action
- Parieto-medial temporal
  - Spatial navigation

Occipito-Parietal Circuit

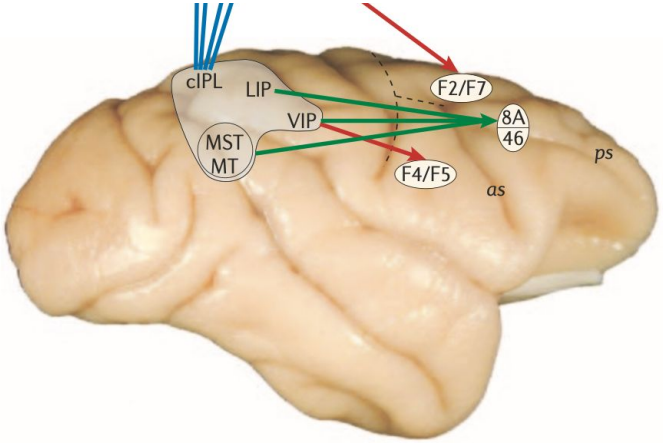
- Transforms purely retinotopic representations into representations in egocentric frames of reference
- Parietal neurons provide information about many egocentric aspects of vision, such as optic flow





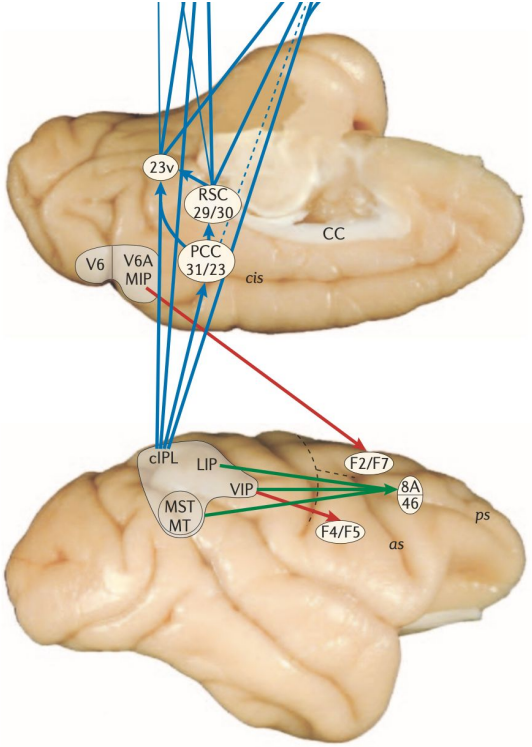
Parieto-Prefrontal Pathway

- Provides input to the prefrontal cortex that is necessary for **visuospatial processing**
- The subregions that give rise to this pathway are strongly involved in **eye movement control**
- Parietal and prefrontal areas are tightly coupled during **spatial working memory tasks**, showing co-activation



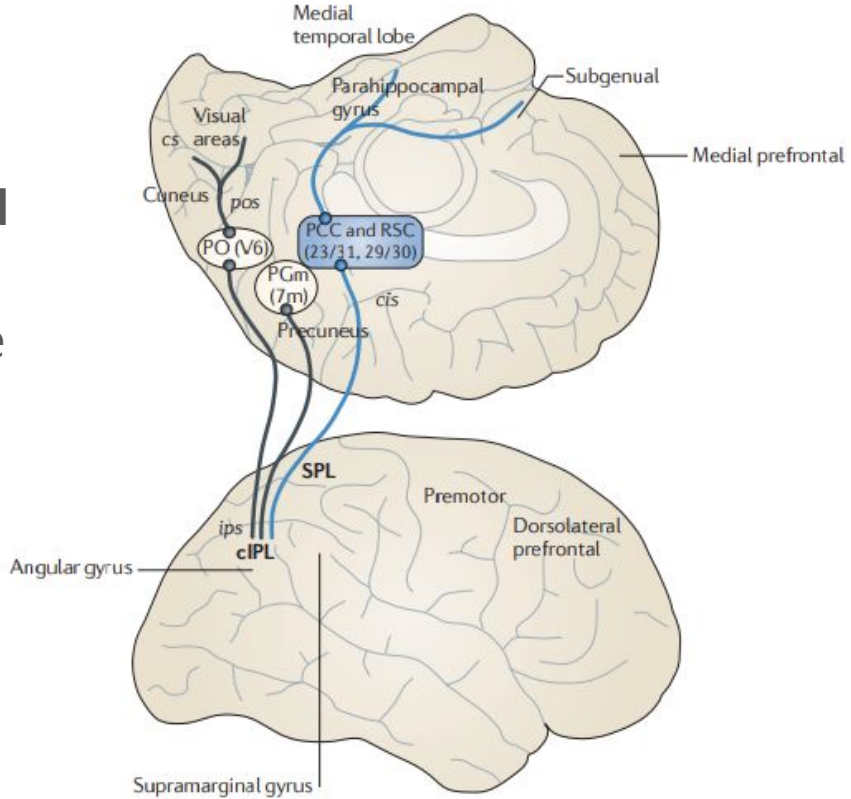
Parieto-Premotor Pathway

- Mediates eye movements, reaching and grasping, and other **visually guided actions**
- Adapts to movements of the observer and **maintains 3D representations of objects**
- Neurons along this pathway are **multi sensory receptive**

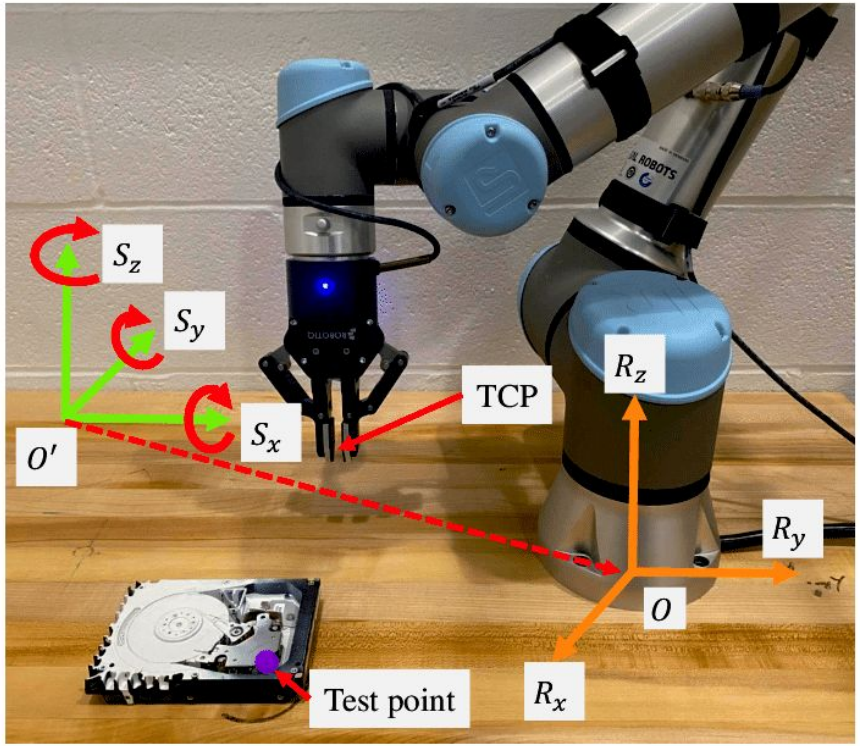


Parieto-Medial Temporal Pathway

- Provides input to the hippocampal formation for **spatial processing and navigating the environment**
- Neurons along this pathway are more specialized for **processing distant space** rather than being involved in guiding the actions of the body



Analogies to Robotics: Coordinate Transforms

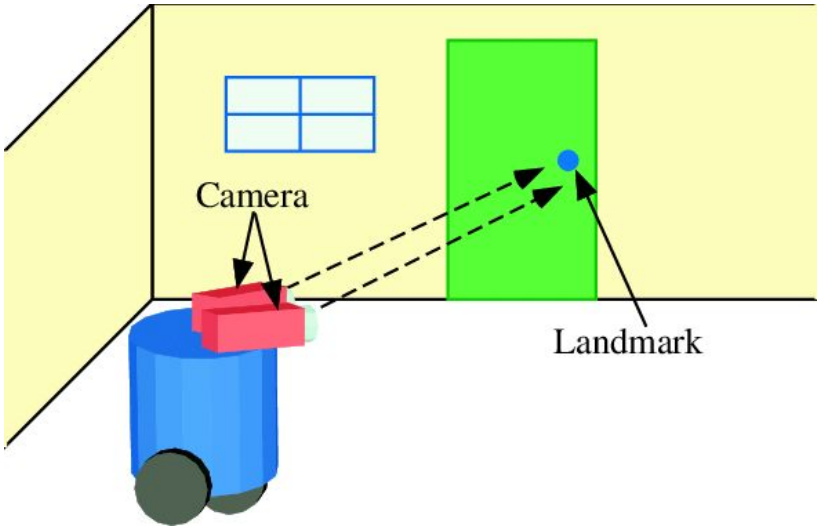


- The functions of the occipito-parietal circuit and parieto-premotor pathway involve the transformation of representations into new coordinate frames

- This is analogous to coordinate transforms in robotics!

Analogies to Robotics: Navigating with Landmarks

- Retrosplenial cortex lesions
  - Subjects can recognize landmarks, but can't orient themselves towards them
- Lingual gyrus (MTL) damage
  - Subjects can't find new landmarks when navigating unfamiliar settings
- Orientation and recognition are distinct tasks
- Recognizing landmarks is not the same as learning new landmarks



Discussion #1 - @104_f1

“This paper makes me wonder if some amount of hand-crafting is necessary in order to achieve human-level perception—how might a deep learning model learn to perform all of these separate subtasks/know which tasks to perform?”

1. In the past we have seen several approaches to generalizable deep learning. Do you think any of those techniques are capable of reproducing the system presented here?
2. In what ways can we use hand-crafting techniques to help a deep learning model more effectively achieve (near) human-level perception?

Discussion #2 - @104_f4

> “How [does] this work fit with examples of neuroplasticity; i.e. the ability for the brain to "retrain" itself after suffering damage. The fact that all members of a species generally share the same brain function mapping suggests brain structure is genetic, yet for some functions it is possible to remove or damage parts of the brain and simply learn other pathways to perform the same function.”

1. Neuroplasticity is an important method used by the brain to circumvent damage to sections of the brain. How can the concept of neuroplasticity be applied to deep learning techniques which mimic the human visual system?