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July 3, 2006
Cognitive Neuroscience of Thought
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Cognitive Neuroscience of Thought


History, evolution, and methods

Plato

Pointing skyward

The Abstract

Ideas
Forms
Universals

Aristotle

Pointing to the earth

The Concrete

Experiences
Perceptions
Particulars

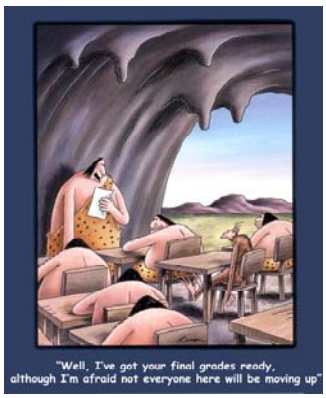
The School of Athens, Raphael (1509)

The modern study of thought

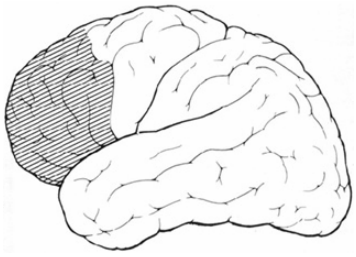
- Emphasis on mental processes and mechanisms
- Strives to determine the "building blocks" or elemental processes of thought
  - e.g., monitoring, manipulation, evaluation, integration, retrieval (all still hotly debated)
- Empirically oriented

Cognitive neuroscience of thought

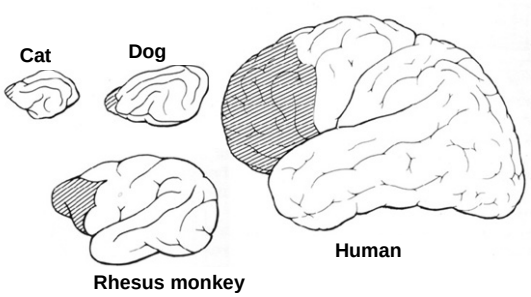
- Uses an empirical approach grounded in the neuroscience field
- Aims to determine the basic psychological processes that comprise human thought
- Combines two parallel levels of scientific investigation
- Borrows additional from a range of disciplines
  - e.g., computational modeling, anthropology, comparative primatology, etc



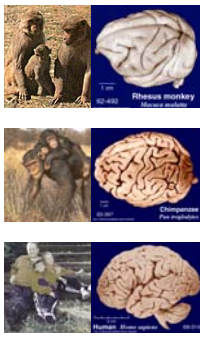
The prefrontal cortex

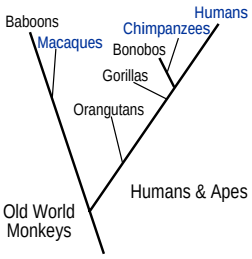


Evolution of Prefrontal Cortex



Primate Evolution

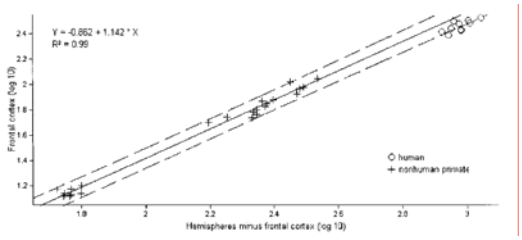




Frontal cortex: absolute size

Human:	**238.8 cm³ – 329.8 cm³**
Great apes:	**50.4 cm³ – 111.6 cm³** (chimp to orangutan)
Lesser apes:	**13.2 cm³ – 16 cm³** (gibbons)
Monkeys:	**13.3 cm³ and 15.1 cm³** (rhesus, cebus)

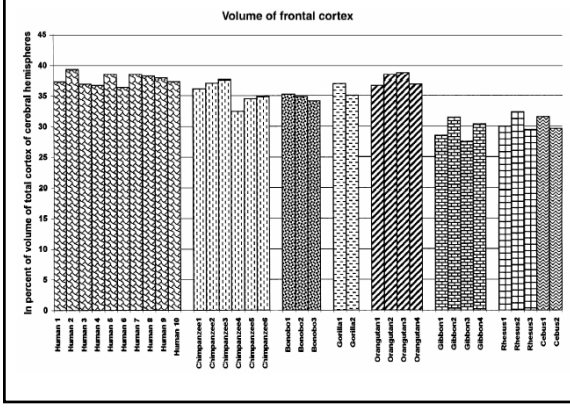
The human frontal cortex is not larger than expected for a primate brain of human size



Semendeferi et al., 2002

The relative size of the frontal cortex

Human	37.7 (± 0.9)
Chimpanzee	35.4 (± 1.9)
Bonobo	34.7 (± 0.6)
Gorilla	35.0 and 36.9
Orangutan	37.6 (± 1.1)
Gibbon	29.4 (± 1.8)
Macaque	30.6 (± 1.5)
Cebus	29.6 and 31.5



Uniquely human abilities

- **Cognitive**
  - **exploration and exploitation of the environment**
- **Social**
  - **interactions with others, emotions, social hierarchies**
- **Self-awareness and self-consciousness**

Uniquely human abilities are most likely due to

1. **differences in individual frontal cortical areas**
2. **richer interconnectivity**

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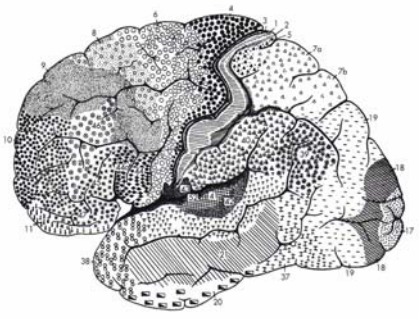
Brodmann's areas

Cytoarchitectonic classification



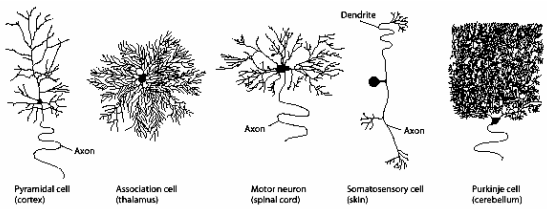
Brodmann Areas (BA)

BA4 - motor cortex, precentral gyrus

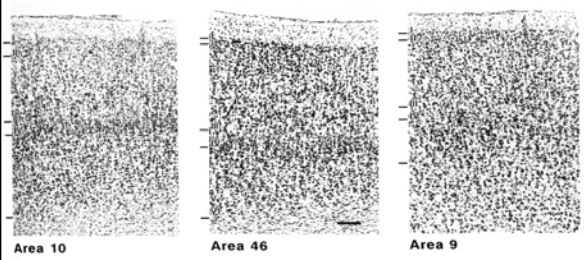
BA6 - lateral premotor cortex
BA8 - supplementary motor area
BA44 - Broca's area

BA47 & 45 - ventrolateral PFC
BA9 & BA46 - dorsolateral PFC
BA10 - frontopolar cortex
BA11 - orbitofrontal cortex
BA24 & 32 - cingulate cortex

Cell typology (cytoarchitectonics)

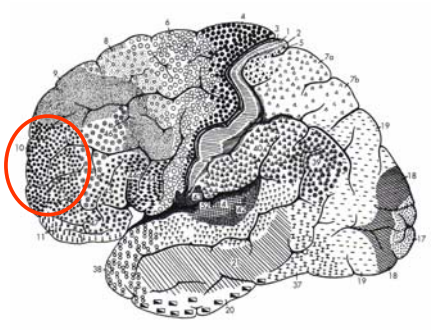


Cytoarchitectonic differences

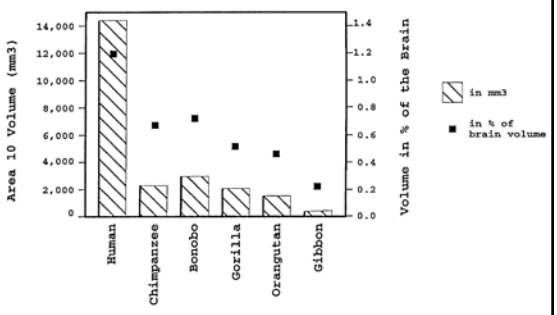


Source: Petrides & Pandya (1994)

Brodmann's area 10



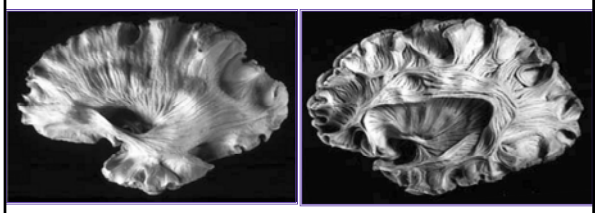
Brodmann's area 10



Uniquely human abilities are most likely due to

1. differences in individual frontal cortical areas

2. richer interconnectivity



Long-range connections (projection & commissural)

Short-range connections (short arcuate fibers)

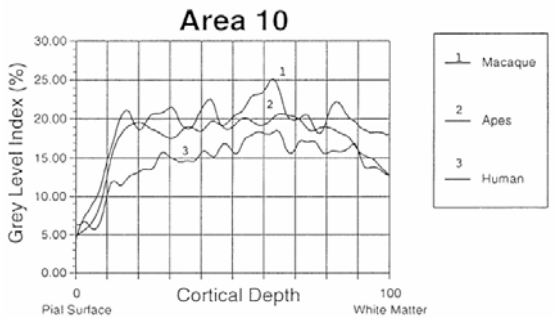
Extrinsic (between areas)
Intrinsic (within an area)

Grey Level Index

- The ratio of grey matter to white matter in particular brain region
- Lower gray level index means
  - higher proportion of white matter
  - richer intrinsic and extrinsic connectivity in this region

Neuronal density (per mm³) in area 10

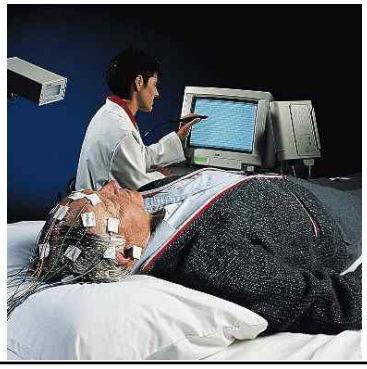
Species	Density of neurons
Human	34,014
Chimpanzee	60,468
Bonobo	55,690
Gorilla	47,300
Orangutan	78,182
Gibbon	86,190



Methods for Observing Neural Activity

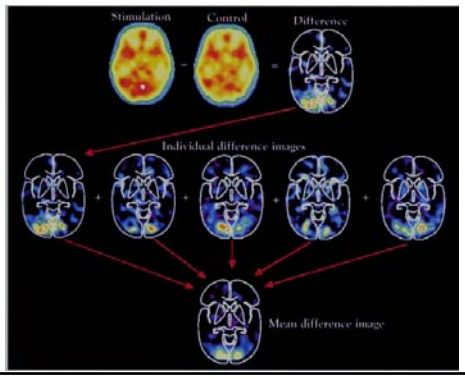
- EEG (Electroencephalography)
- MEG (Magnetoencephalography)
- PET (Positron Emission Tomography)
- fMRI (functional Magnetic Resonance Imaging)
- TMS (Transcranial Magnetic Stimulation)

EEG - Electroencephalography



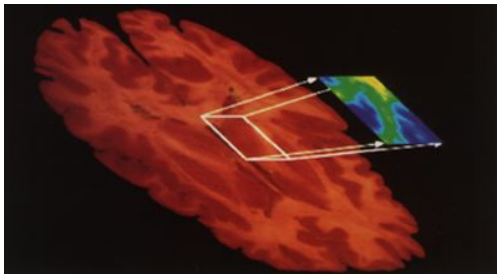
PET
Positron Emission Tomography

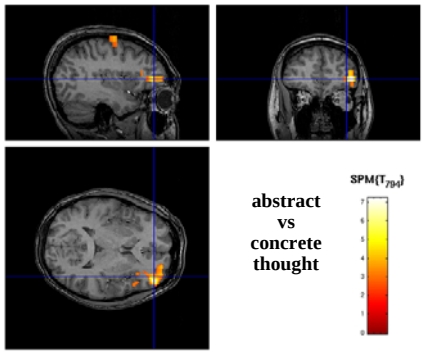
Cognitive subtraction



fMRI

Functional Magnetic Resonance Imaging

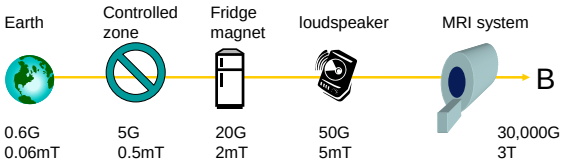




Static magnetic fields

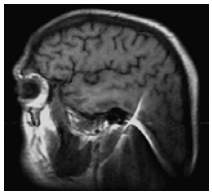
Units:

- **Tesla - SI Unit of magnetic flux density**
- **Gauss - old measure**
- **1 Tesla = 10,000 Gauss**

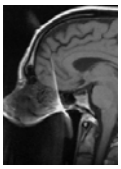


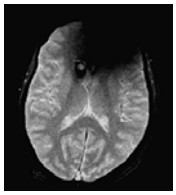
Artefacts

- Metal objects distort magnetic field and give rise to image artefacts



Hair grip





Metal dental work

fMRI vs. PET

- **Advantages of PET**
  - Chemical specificity
  - Not subject to magnetic artifacts
  - Better understood
  - Quiet -- verbal responses allowed
  - Motion not as devastating to analysis
- **Advantages of fMRI**
  - Cheaper, more accessible
  - Better spatial and temporal resolution
  - Noninvasive (repeated experiments possible)
  - Can collect both structural and functional images

Discussion groups

- Discuss ideas for **experiments** (addressing topics raised in class - or others).
- Discuss ideas and methods for **meta-analyses** of neuroimaging studies.
- **To receive credit**: write a 5-page paper, proposing an experiment to study a question related to one of the topics covered in the lectures.