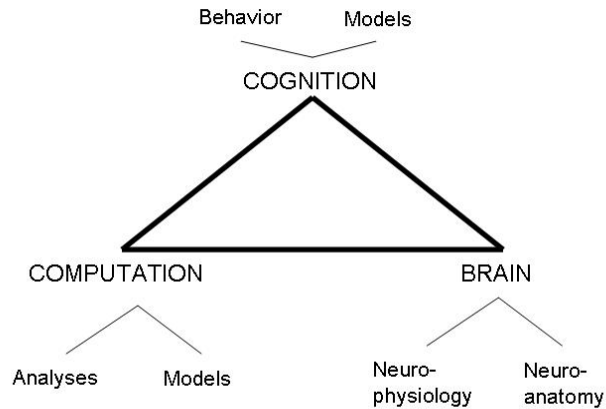


# Cognitive Neuroscience

## Methods of Cognitive Neuroscience



The cognitive neuroscience triangle can be used to categorize the methods of cognitive neuroscience used to study the relation between brain function and cognition:

1. Behavioral Analysis
2. Neurophysiology
3. Neuroanatomy
4. Computational Analysis
5. Computational Modeling (Cognitive & Neural)
6. Perturbation Methods

# 1. Behavioral Analysis

## a. Types

Verbal (e.g. naming an object)

Nonverbal (e.g., pressing a button)

## b. Measurement

Behavioral analysis often involves measuring the *response time* (delay after a stimulus) and/or *accuracy* (fraction of correct responses)

## c. Applications

*Task analysis* examines the behavior of subjects engaged in experimental tasks

*Lesion analysis* examines the behavioral consequences of accidental or therapeutic brain lesions in humans and experimental brain lesions in animals

## d. Tests

Delayed matching tasks

Stroop Test

Wisconsin Card Sorting Task (WCST)

Sternberg Paradigm

## 2. Neurophysiology

### a. Neuron (unit) activity

*Single-unit*: spike trains from single isolated neurons in the brain

*Multi-unit*: spike trains from multiple neurons in the brain

### b. Population (field potential or field) activity

*Electroencephalogram (EEG)*: recording of cortical electrical activity from extracranial sensors

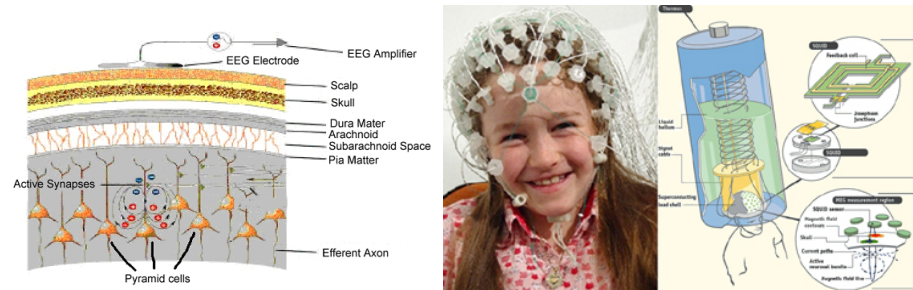
*Magnetoencephalogram (MEG)*: recording of cortical magnetic activity from extracranial sensors

*Local Field Potential (LFP)*: recording of cortical electrical activity from microelectrodes in cortex

*Intracranial EEG (iEEG)*: recording of cortical electrical activity from macroelectrodes in cortex

*Electrocorticogram (ECoG)*: recording of cortical electrical activity from macroelectrodes on surface of cortex

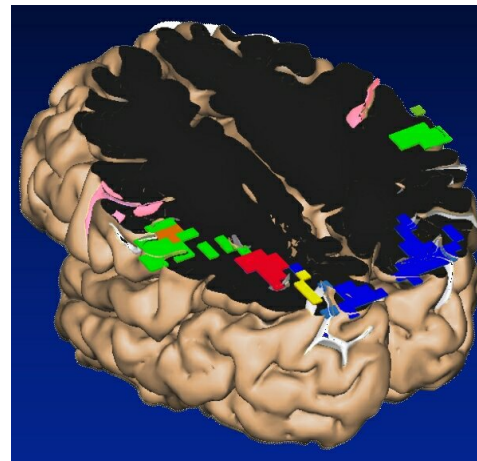
The Event-Related Potential (ERP) is derived from the EEG, LFP, iEEG, or ECoG by a 2-step process: (1) alignment of multiple time traces to a common sensory, cognitive, or motor event; (2) averaging the traces at each time point. The ERF is produced from the MEG by the same process.



### c. Functional brain imaging

*Positron Emission Tomography (PET)*: tomographic imaging of brain activity from emitted gamma rays from radioactive tracers

*Functional Magnetic Resonance Imaging (fMRI)*: tomographic imaging of brain activity from the Blood Oxygen Level Dependent (BOLD) signal



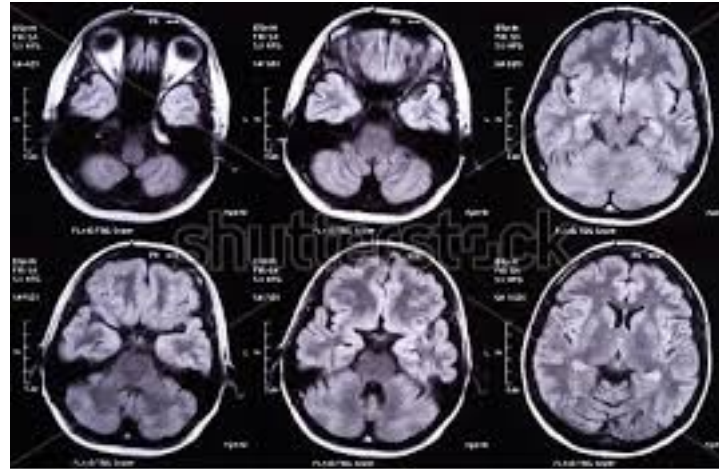
The use of PET and fMRI in cognitive neuroscience is based on the concept that the neurons in brain regions which are involved in a cognitive function increase their metabolic activity during that function.

Ex 1: in FDG PET imaging, a radioactively labeled glucose analog is injected into the bloodstream, is taken up into the brain, and then in higher amounts in metabolically active cortical neurons.

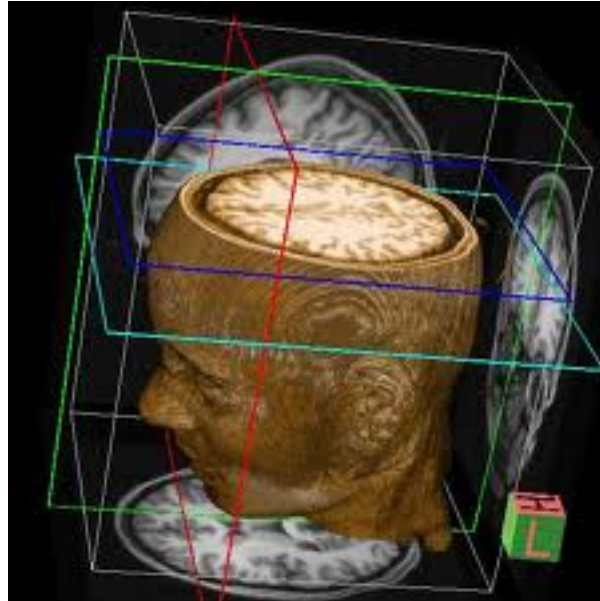
Ex 2: in fMRI BOLD imaging, the ratio of oxygenated to un-oxygenated hemoglobin in the red blood cells of the local microcirculation is lower in metabolically active cortical regions.

### 3. Neuroanatomy

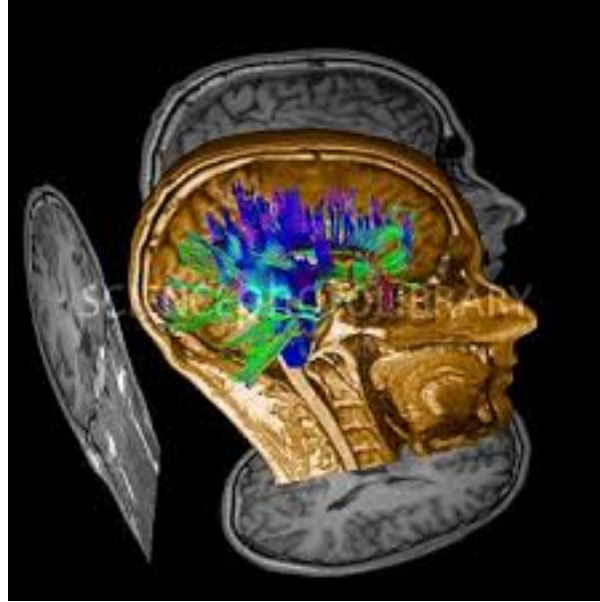
a. *X-ray Computed Tomography (CT)*: 2D and 3D images of the brain are constructed by tomography from differences in x-ray absorption



b. *Structural Magnetic Resonance Imaging (sMRI)*: 2D and 3D images of the brain are constructed by tomography from differences in the radio frequency signal of excited hydrogen atoms as they return to their equilibrium states



c. *Tractography*: 3D modeling techniques that image brain pathways (tracts) using *diffusion tensor imaging (DTI)* or *diffusion spectrum imaging (DSI)*, two variants of magnetic resonance imaging. Diffusion imaging maps the diffusion of water molecules in the brain.





## 4. Computational Analysis

### a. Logical analysis

Determination of the computational (information processing) steps necessary to perform a cognitive process

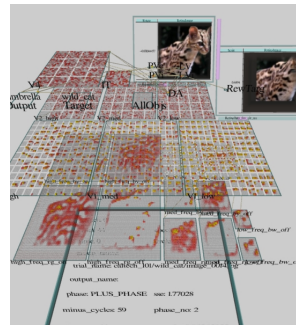
### b. Simulations

Artificial generation of imitations (or reproductions) of cognitive processes, usually in a digital computer but also in other hardware such as robots

## 5. Computational Modeling

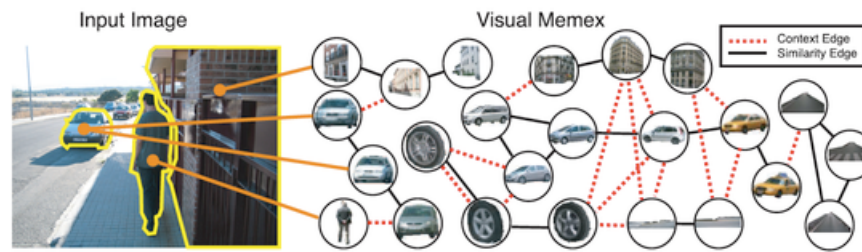
### a. Artificial Neural Network Models (PDP approach)

Models of cognitive processes constructed from ANNs having simple non-algorithmic function



### b. Symbolic Models (SSP approach)

Models of cognitive processes constructed from symbolic elements having algorithmic function



## 6. Perturbation Methods

### a. Pharmacology

Pharmacological perturbation is a technique that involves administration of chemical agents that affect brain function

### b. Electrical Brain Stimulation

Electrical stimulation of brain regions or pathways with indwelling electrodes

### c. Transcranial Magnetic Stimulation (TMS)

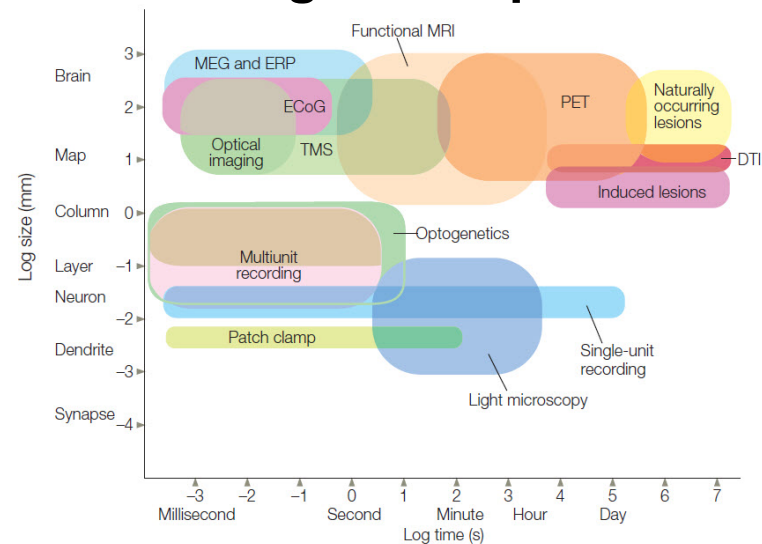
A noninvasive technique for stimulating focal brain regions in healthy humans. It can be used either to activate a region or to produce a “virtual lesion” by disrupting ongoing activity.

### d. Transcranial Direct Current Stimulation (tDCS)

A noninvasive technique similar to TMS that uses electrical rather than magnetic stimulation.

Both TMS and tDCS are used in conjunction with sMRI to localize the target region

## Temporal scale, spatial scale, invasiveness: 3 important dimensions of neural recording techniques



**FIGURE 3.41 Spatial and temporal resolution of the prominent methods used in cognitive neuroscience.** Temporal sensitivity, plotted on the x-axis, refers to the timescale over which a particular measurement is obtained. It can range from the millisecond activity of single cells to the behavioral changes observed over years in patients who have had strokes. Spatial sensitivity, plotted on the y-axis, refers to the localization capability of the methods. For example, real-time changes in the membrane potential of isolated dendritic regions can be detected with the patch clamp method, providing excellent temporal and spatial resolution. In contrast, naturally occurring lesions damage large regions of the cortex and are detectable with MRI.

EEG (ERP), MEG (ERF), fMRI, and PET are the 4 techniques currently most used to record neural data in humans. The first 2 have good temporal resolution but poor spatial resolution. The field of view question is complicated. The other 2 have good spatial resolution and field of view, but poor temporal resolution. The first 3 are non-invasive. The 4<sup>th</sup> involves exposure to radioactive substances. Unit activity (multi- and single-) is the technique currently most used to record neural data in experimental animals. It has good temporal and spatial resolution, but poor field of view. It is invasive.