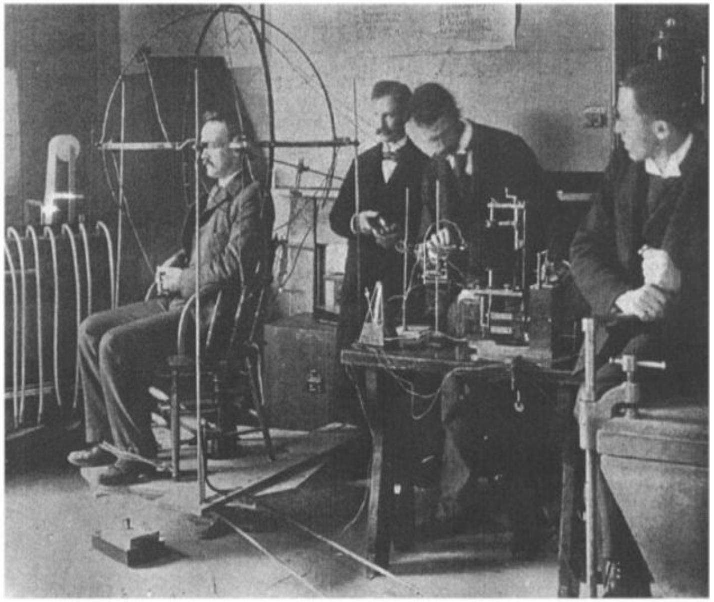
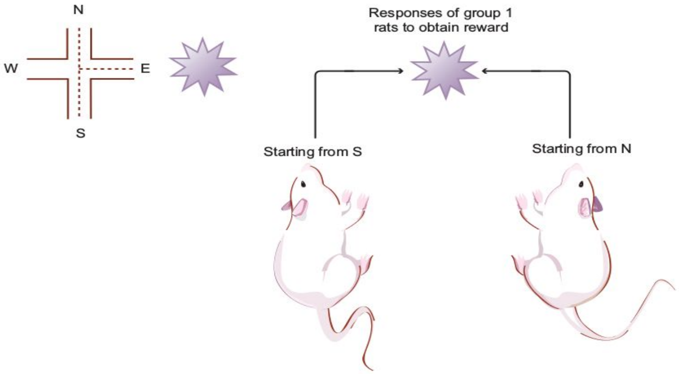
COGS500/CMPE489
Introduction to Cognitive Science
Week III

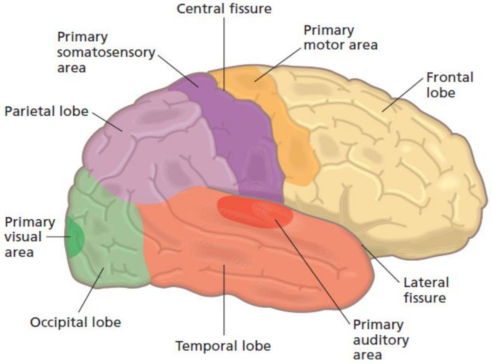
Emre Uğur
Computer Engineering
Bogazici University

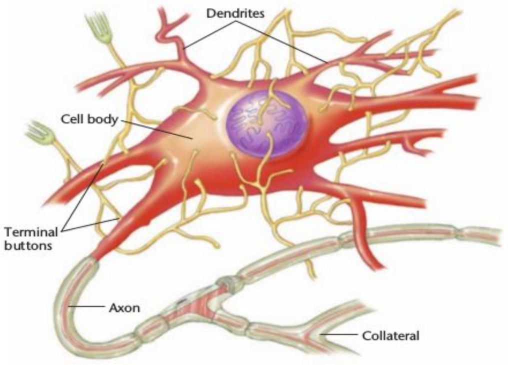
Previously

- Psychology
- Nervous system and brain
  - Nervous system
  - Cerebral cortex







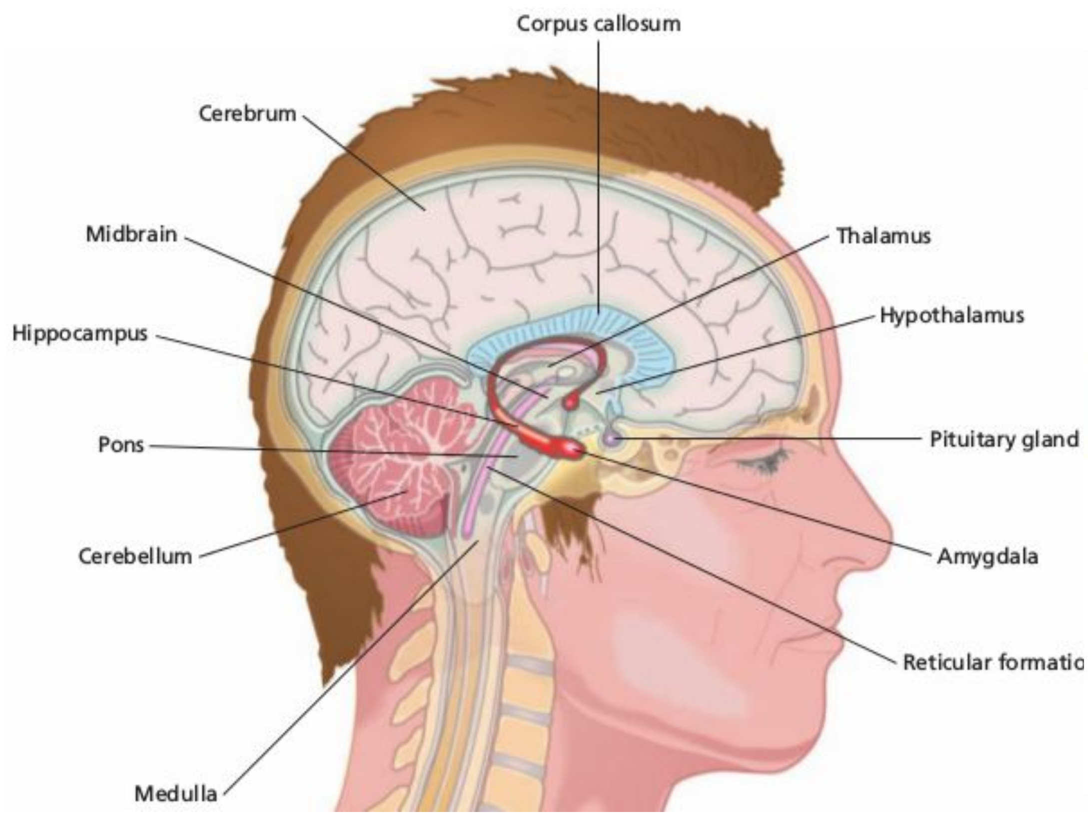


Last lecture: Functional organization

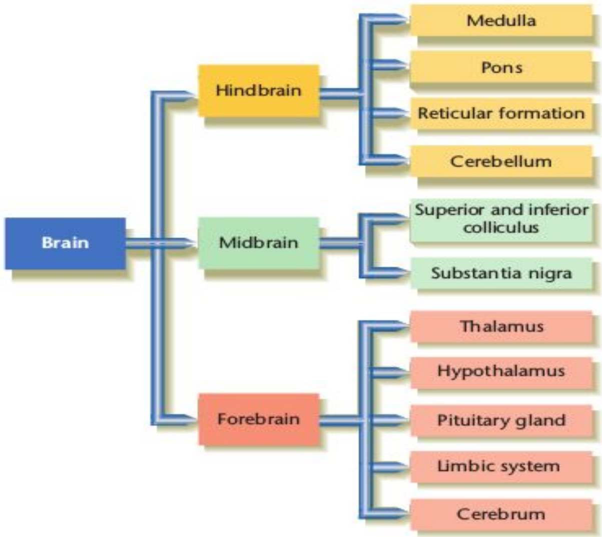
Central core: the most primitive behaviors

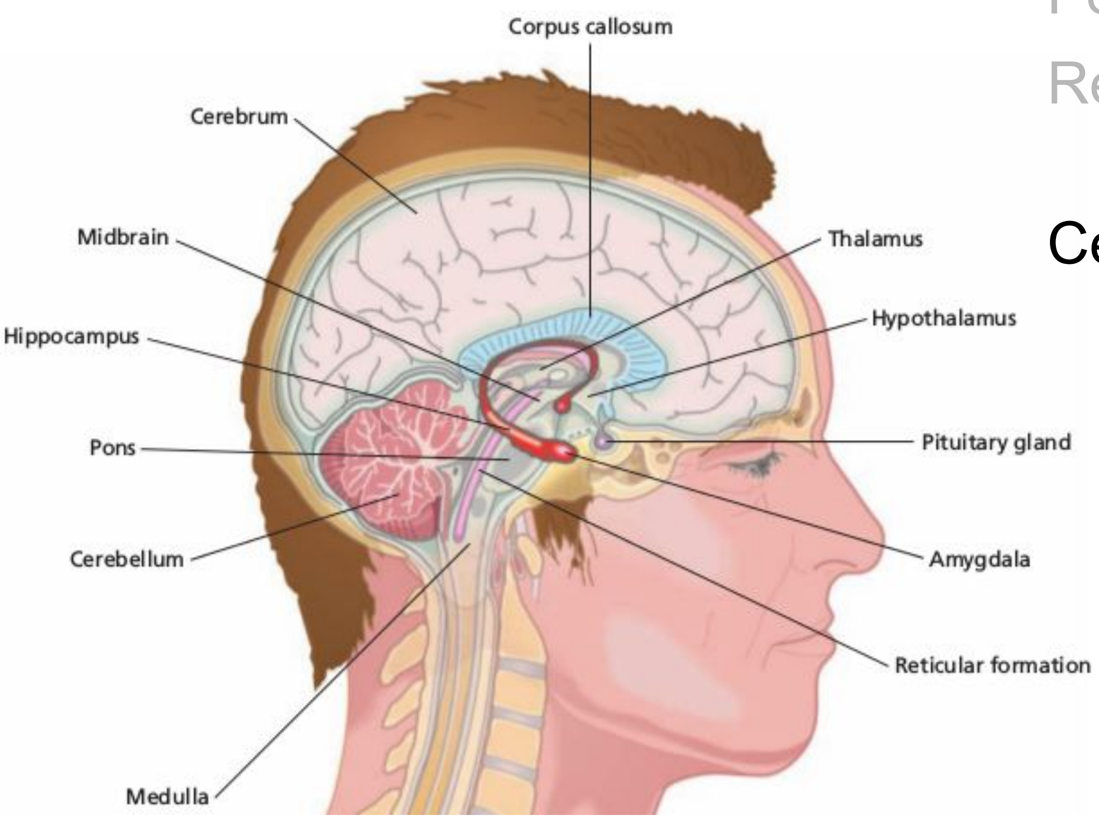
Limbic system: controls our emotions

Cerebrum: regulates our higher intellectual processes

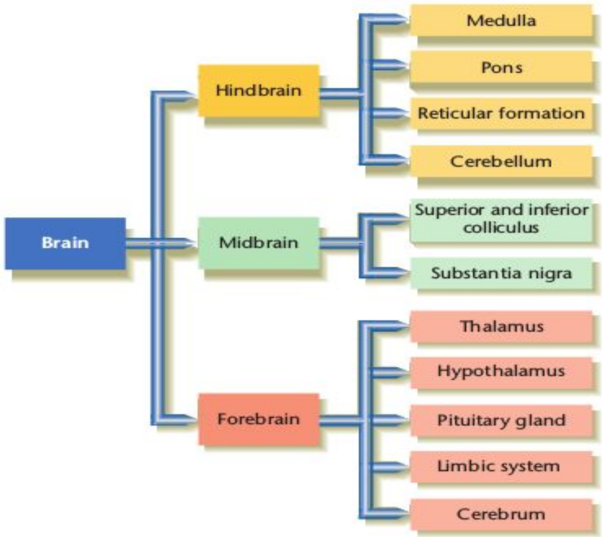


The organization of the brain - Hindbrain



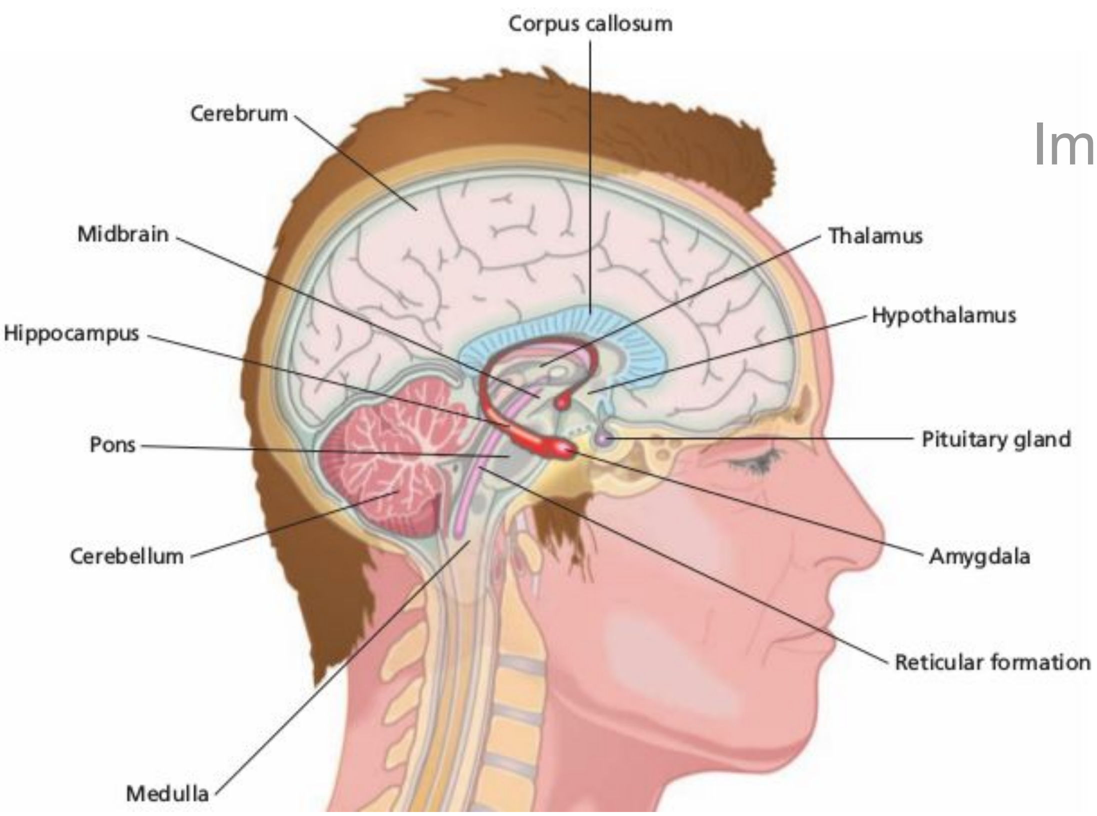


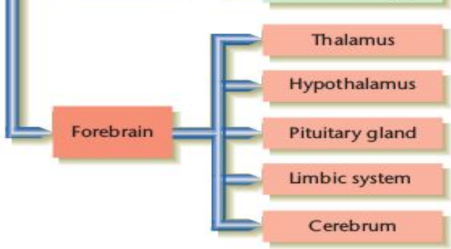
- Medulla: reflexes (breathing and posture)
- Pons: Attentiveness and sleep
- Reticular formation: Behavioral arousal and consciousness
- Cerebellum: coordination of movement. Damage?
  - Learning new movements
  - Direct connections to frontal

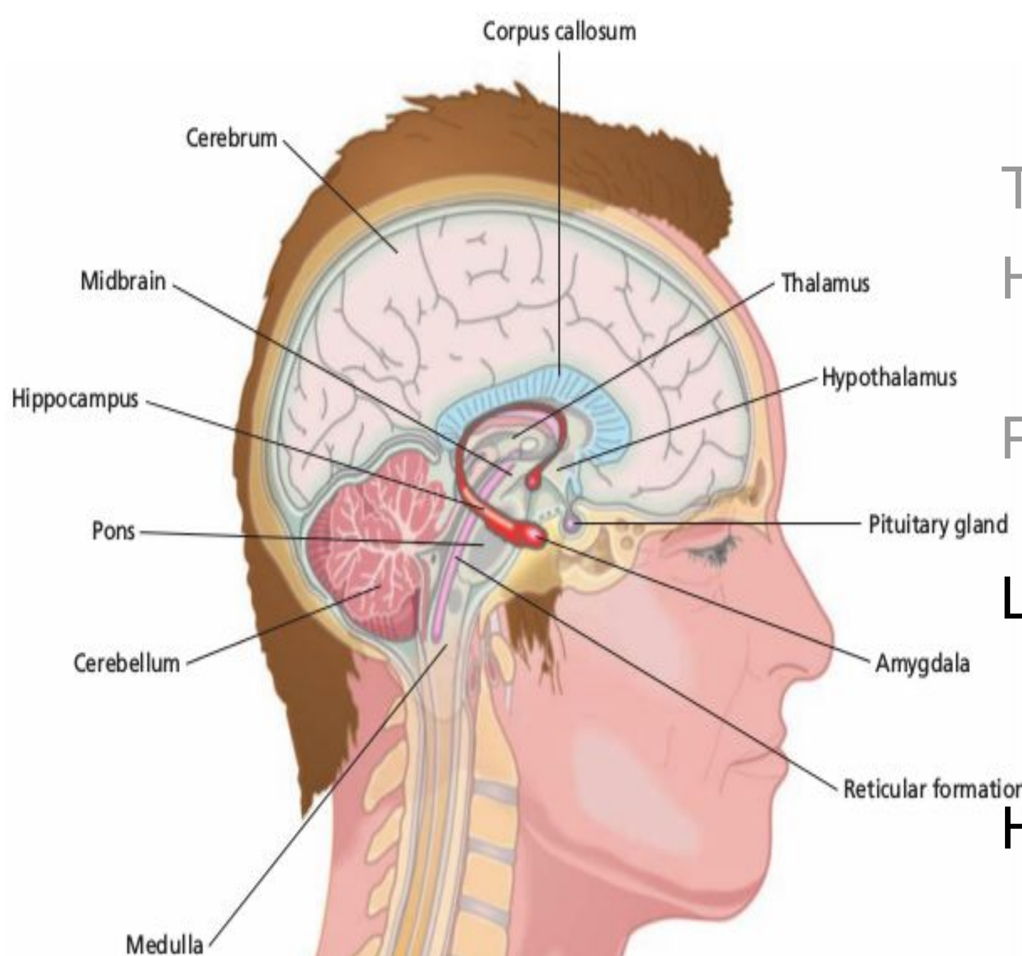


The organization of the brain - Midbrain

- Relaying sensory information to the brain and for movement control (including eye)
- Important part of dopamine-containing pathway (reward pathway).







Forebrain

Large cerebrum.

- Upper part: cerebral cortex
- Subcortical: hippocampus, basal ganglia, olfactory bulb

Thalamus: sensory relay station.

Hypothalamus: eating, drinking, and sexual behavior.

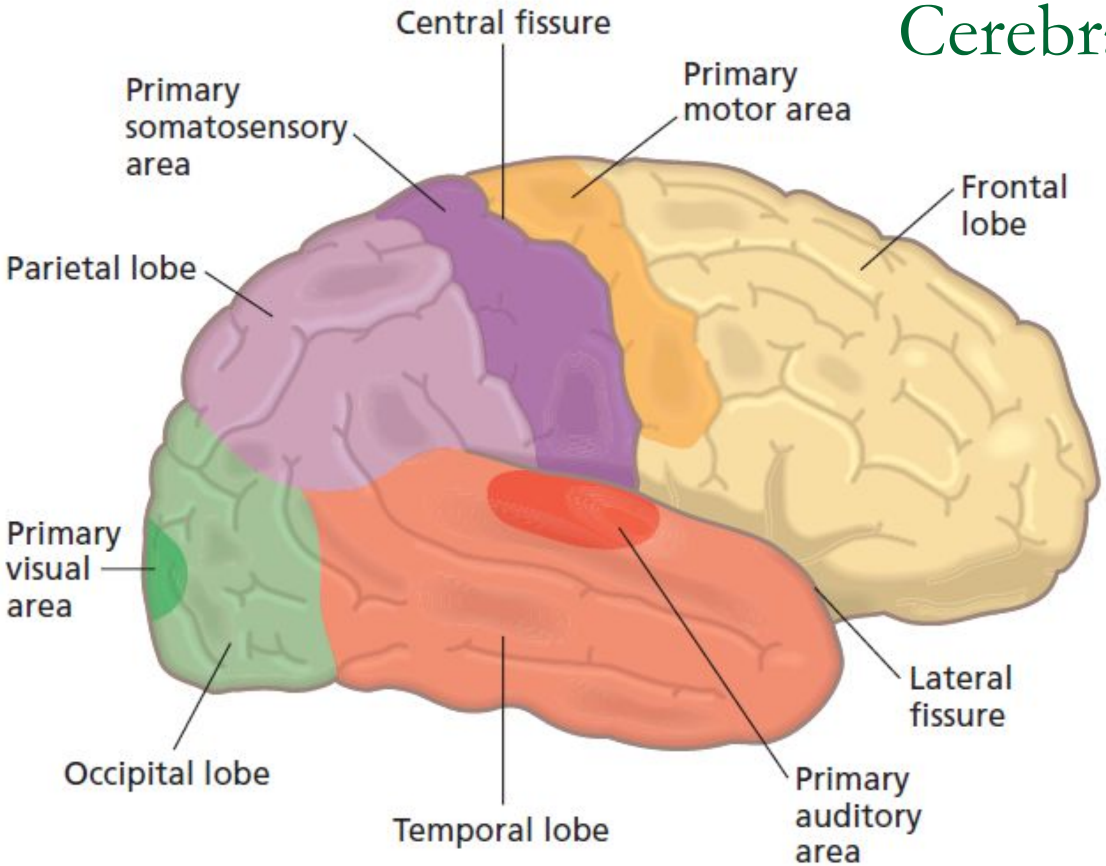
Pituitary gland: part of endocrine sys.

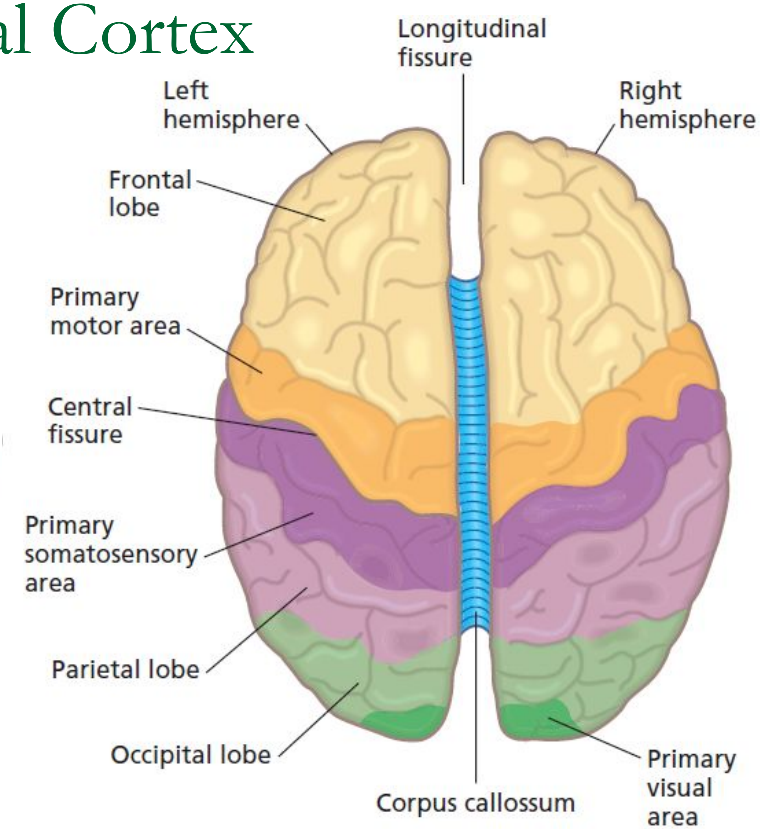
Limbic system: instinctive behaviors regulated by central core.

Hippocampus (part of libmic) role in memory.

Amygdala: critical in emotions such as fear. Damage in amygdala?

Cerebral Cortex

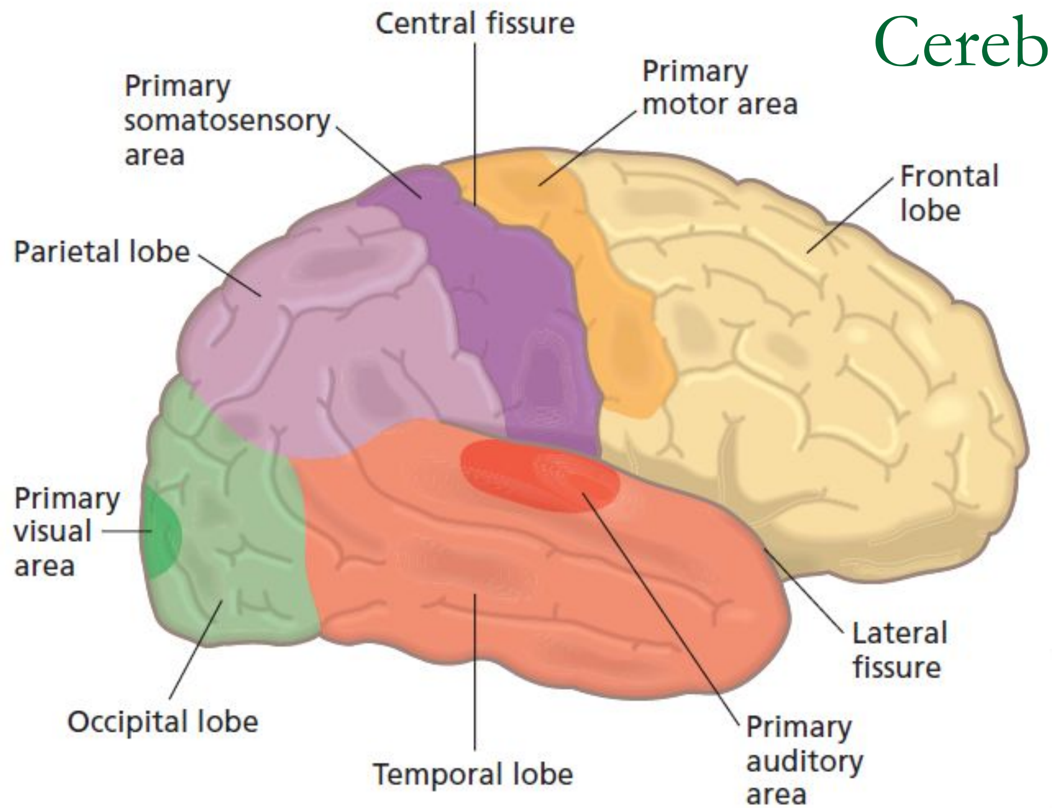




sagittal plane

- 2 symmetrical hemispheres, connected by corpus callosum.
- 4 lobes.
- Frontal/parietal: central fissure
- Lateral fissure: sets off the temporal
- Sensory and motor systems

Cerebral Cortex Sensory/motor



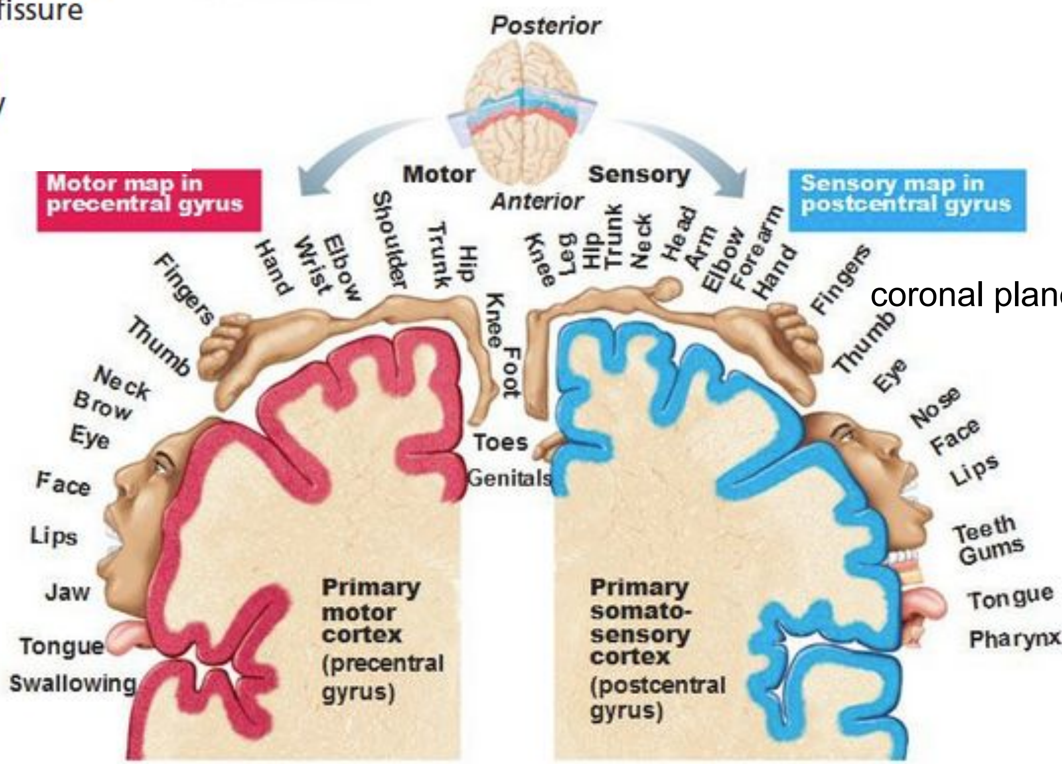
Voluntary movements.

Sensory experiences.

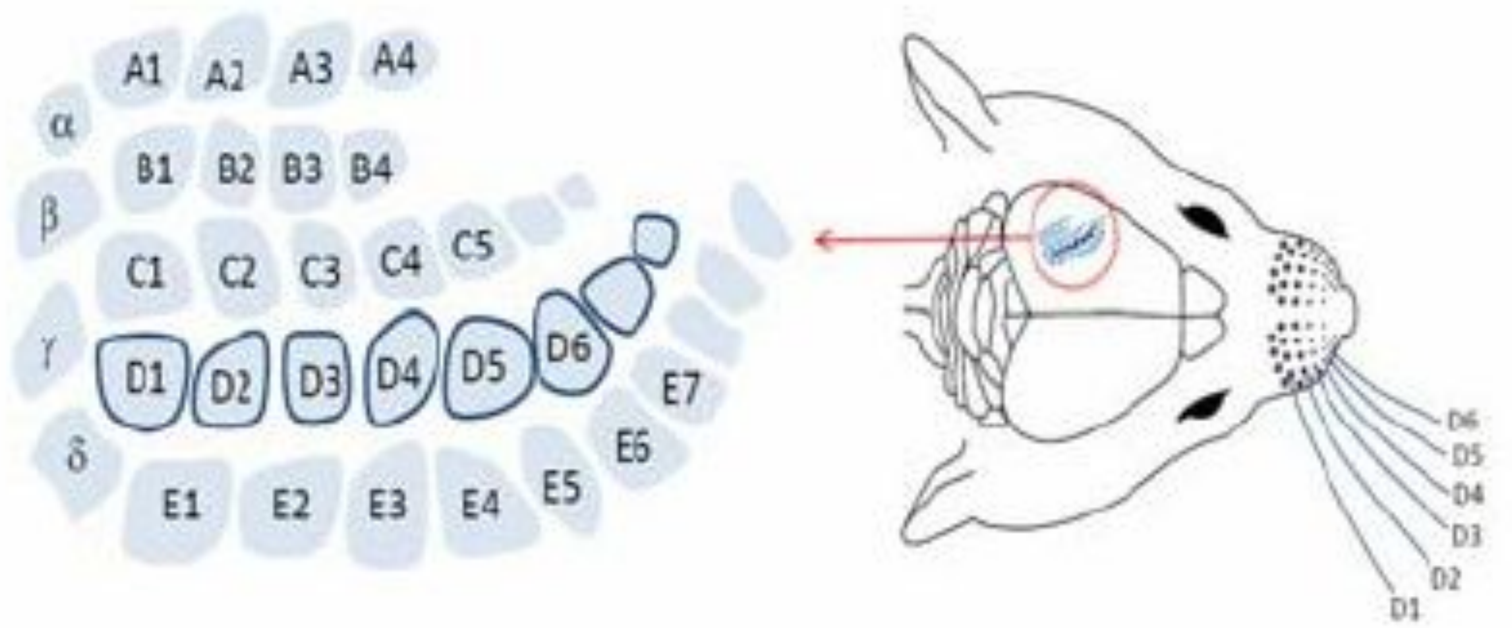
Upside-down.

Right - left.

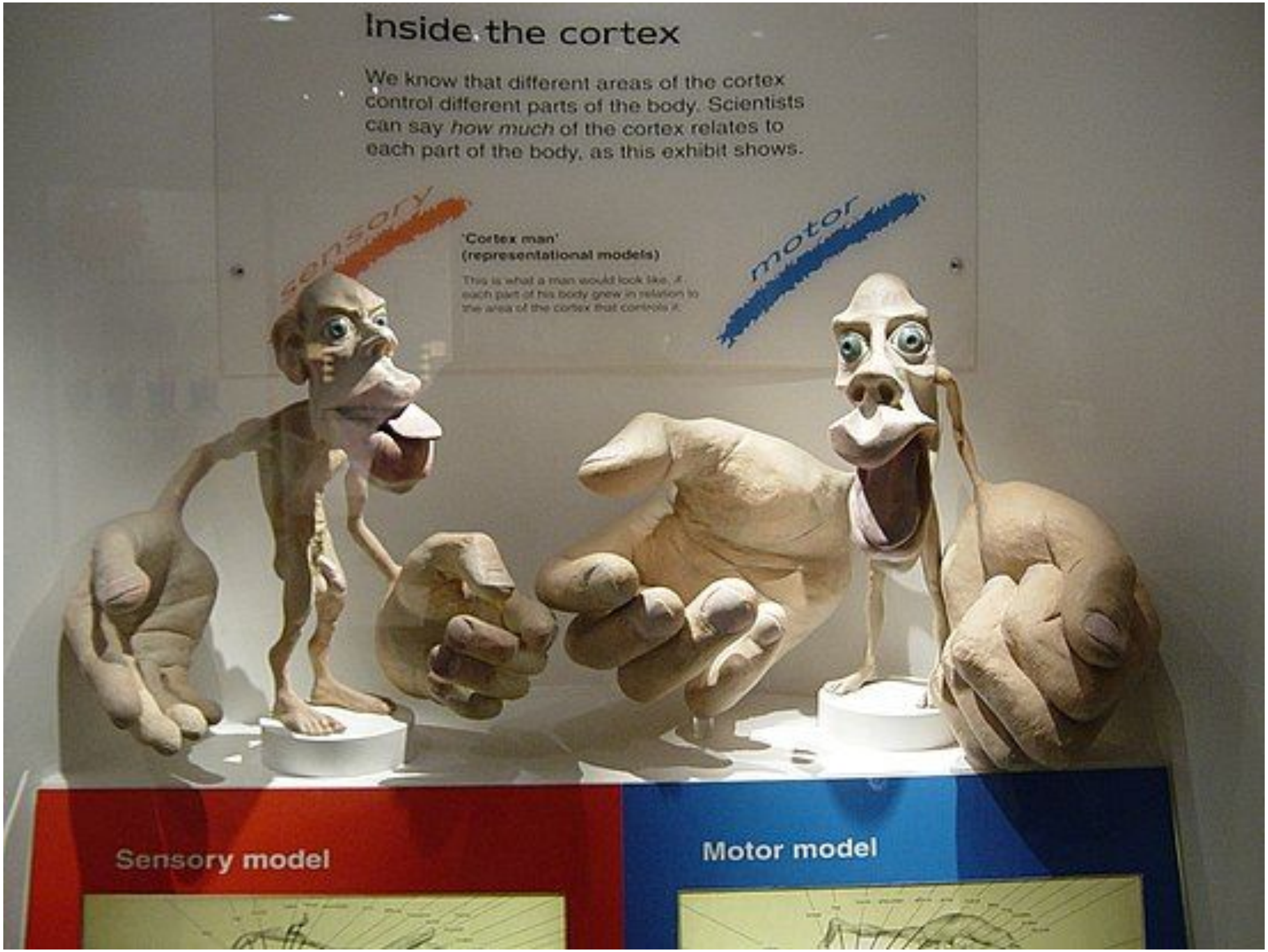
Size of areas



coronal plane

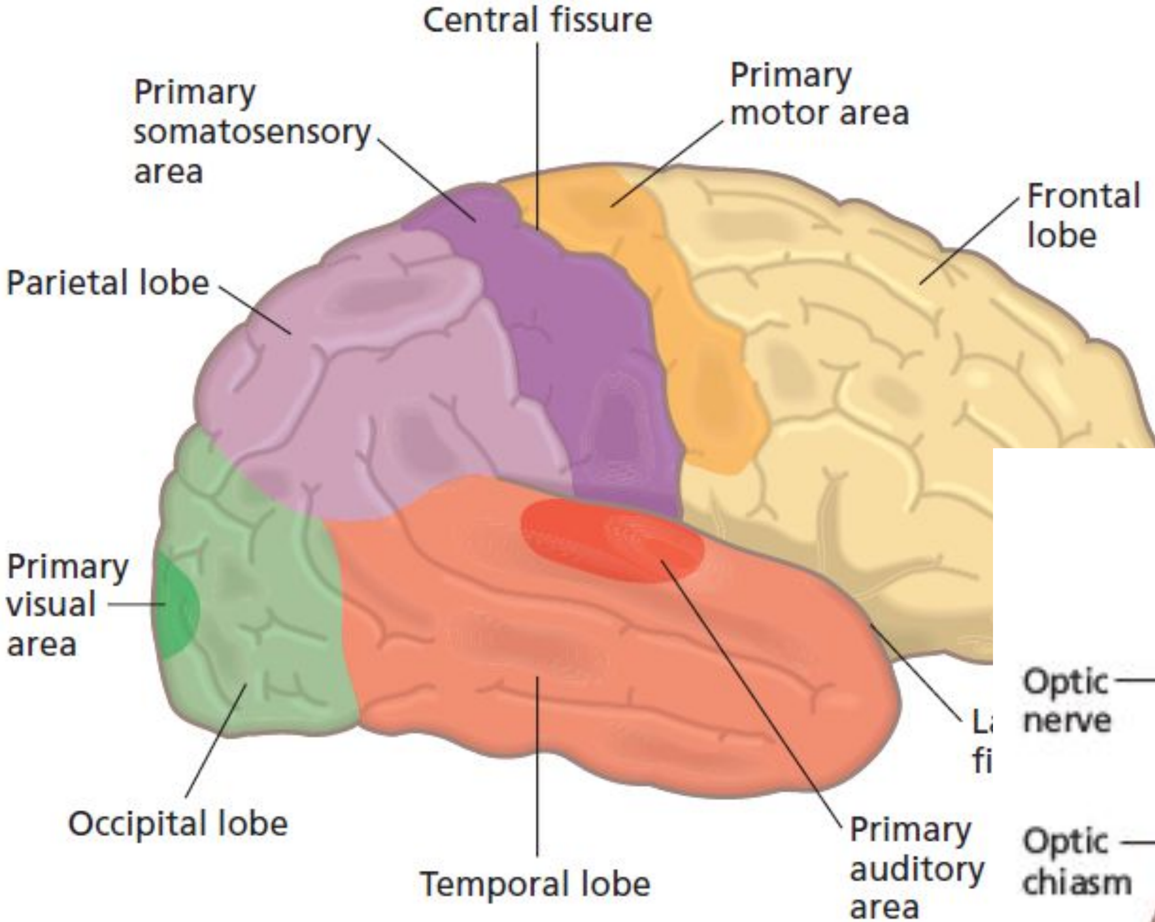


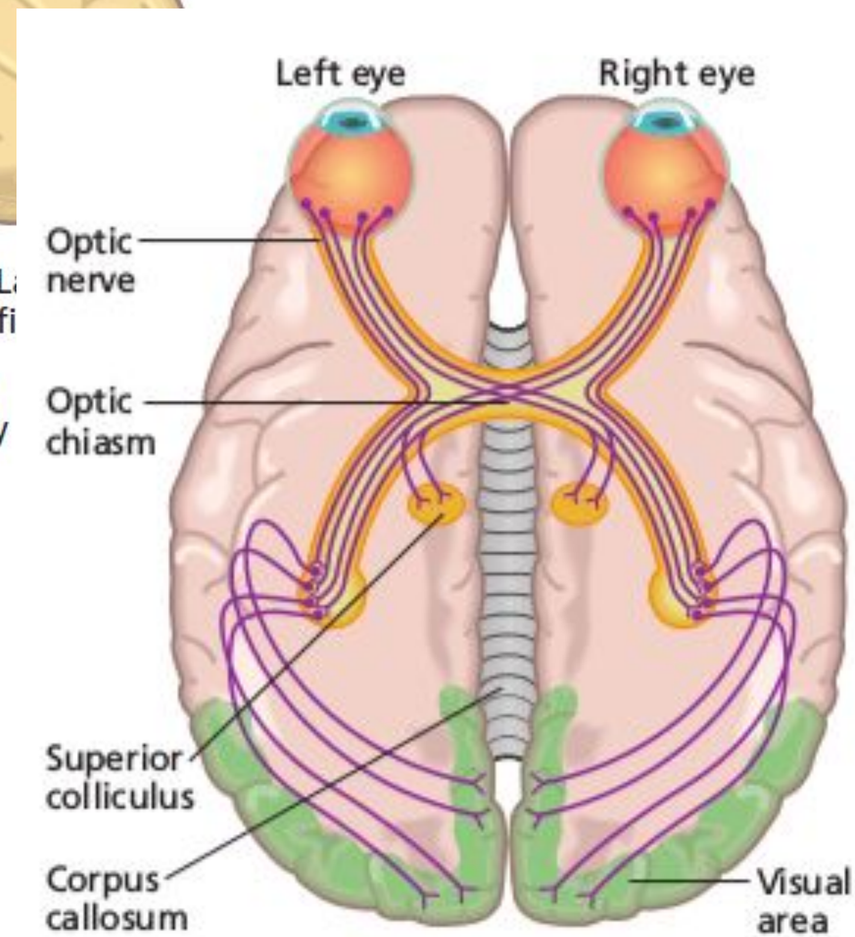
https://www.researchgate.net/figure/Reconstruction-of-recording-sites-in-rat-whisker-barrel-cortex_fig1_261041056



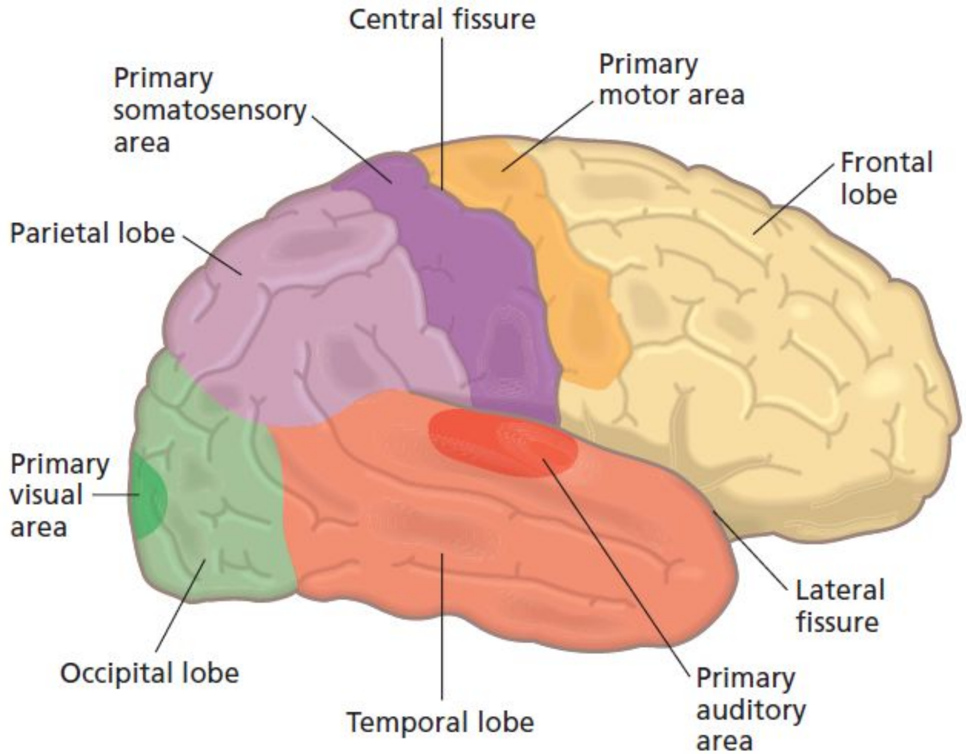
Sensory and Motor homunculus models at the Natural History Museum, London

Cerebral Cortex
Visual/auditory



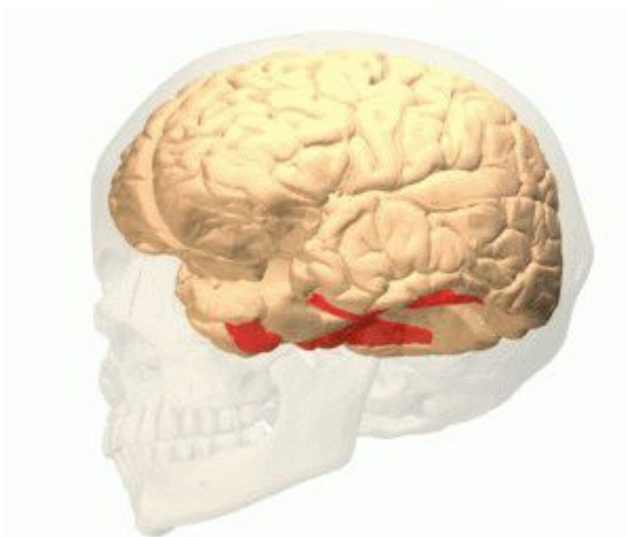


Cerebral Cortex - association areas

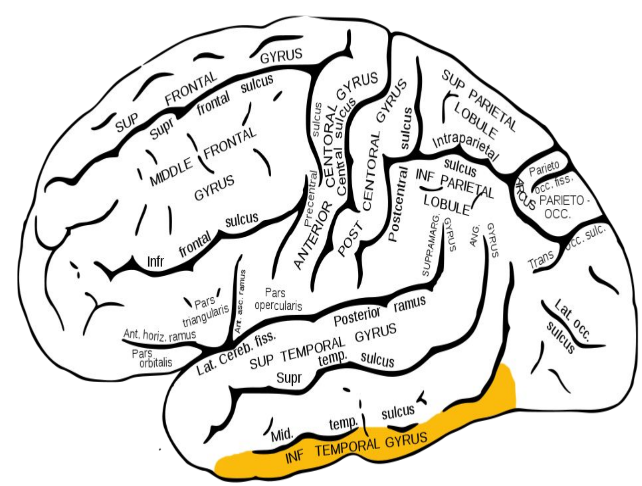


Frontal association areas: memory in problem solving. with damaged frontal lobe (Miller & Cohen, 2001)

Posterior association areas: near primary sensory areas, lower temporal lobe is for visual perception.



fusiform face area – FFA prosopagnosia

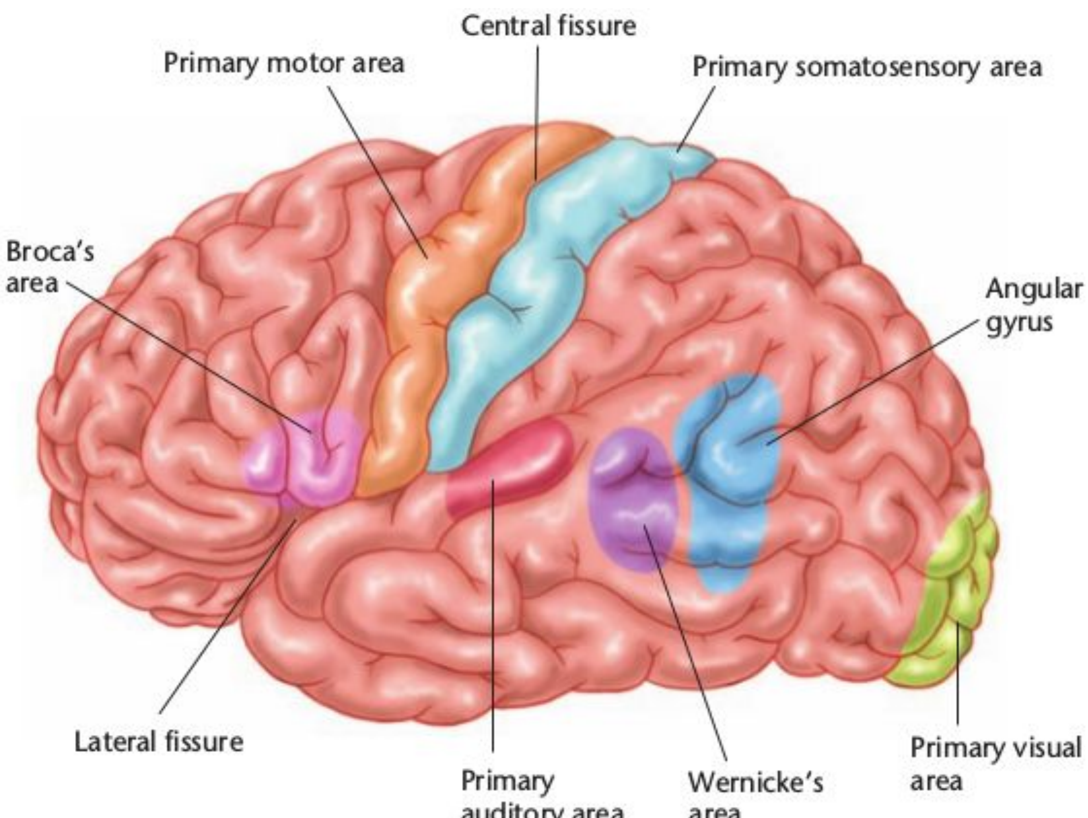


Inferior temporal gyrus, Visual agnosaia

Cerebral Cortex - language

Paul Broca

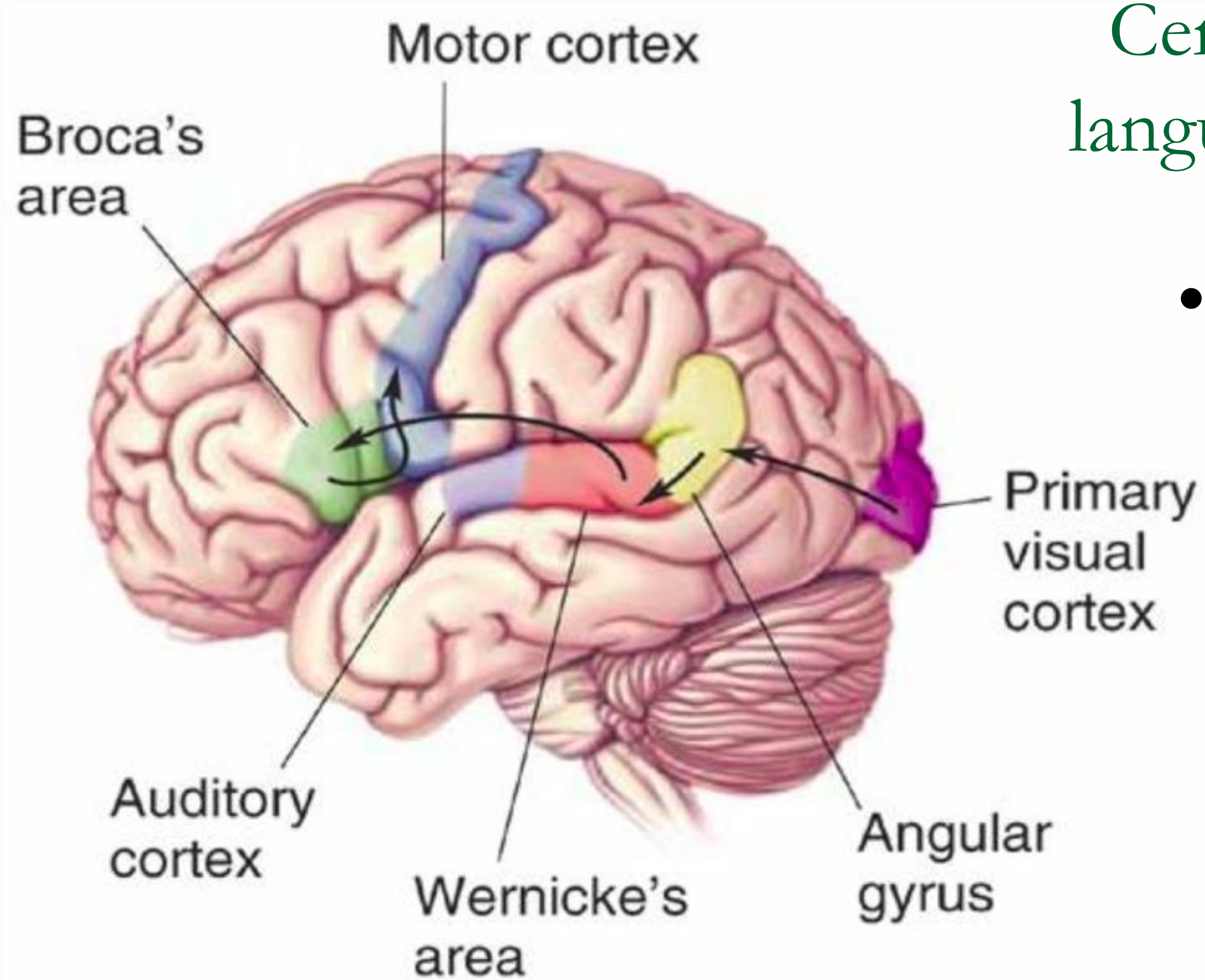
Carl Wernicke



- Broca's area
- Wernicke's area
- Wernicke-Geschwind model
  - Broca's area: articulatory codes
  - Wernicke's area: auditory codes and word meanings

  - Speak a word?
  - Understand a spoken word?
  - Understand a written word?

Cerebral Cortex - language



- Damages @
  - Broca's area?
  - Auditory area?
  - Wernicke's area?
  - Angular gyrus?

https://brainstuff.org/blog/what-is-the-wernicke-geschwind-model

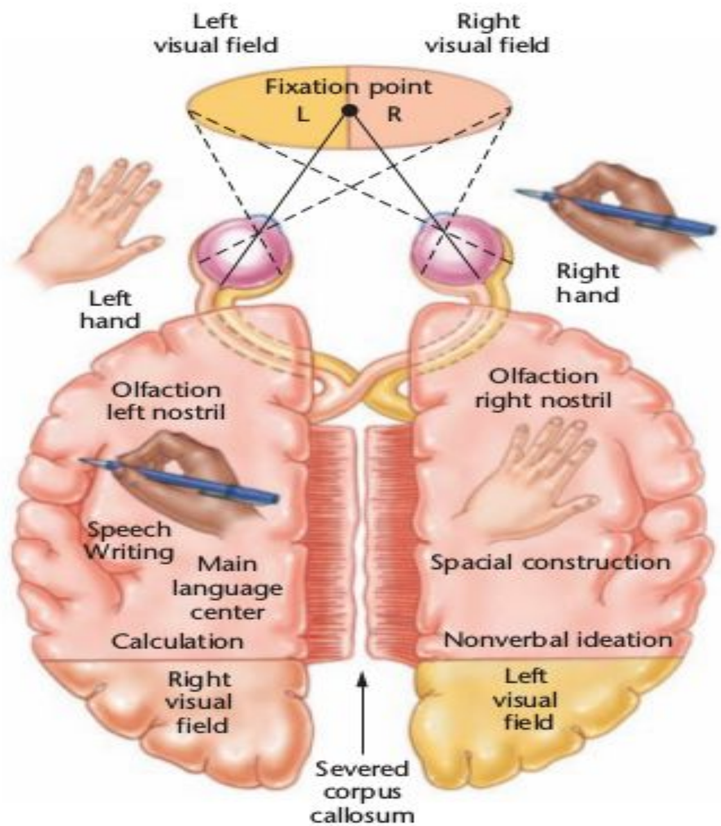
Language

- Wernicke-Geschwind model: Broca's area stores articulatory codes. Wernicke's area auditory codes and meanings of words

- Damage limited to Broca's area: speech production
- Damage to Wernicke's area: all aspects of language comprehension
- Damage to angular gyrus: cannot read, but can speak or comprehend spoken.
- Damage in auditory area: read and speak but

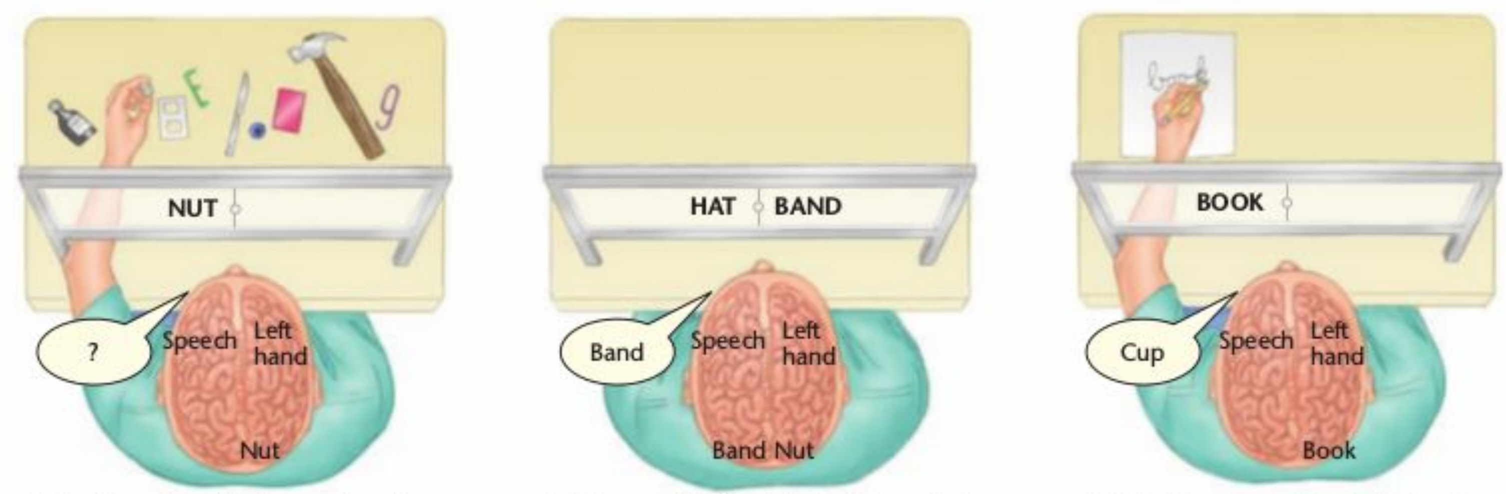
Split-brain research

- Epilepsy patients, seizure starting in one hemisphere may trigger massive response. Therefore, corpus collasum is distrupted.
- Roger Sperry, Nobel Prize in 1981.



Split-brain research

- Roger Sperry, Nobel Prize in 1981.
- 'nut' was not transferred. When questioned, seems unaware of what his left hand is doing.
- 10 seconds, otherwise eye moves and info goes to both sides.
- If blindfolded, some object is placed on left hand, can use.

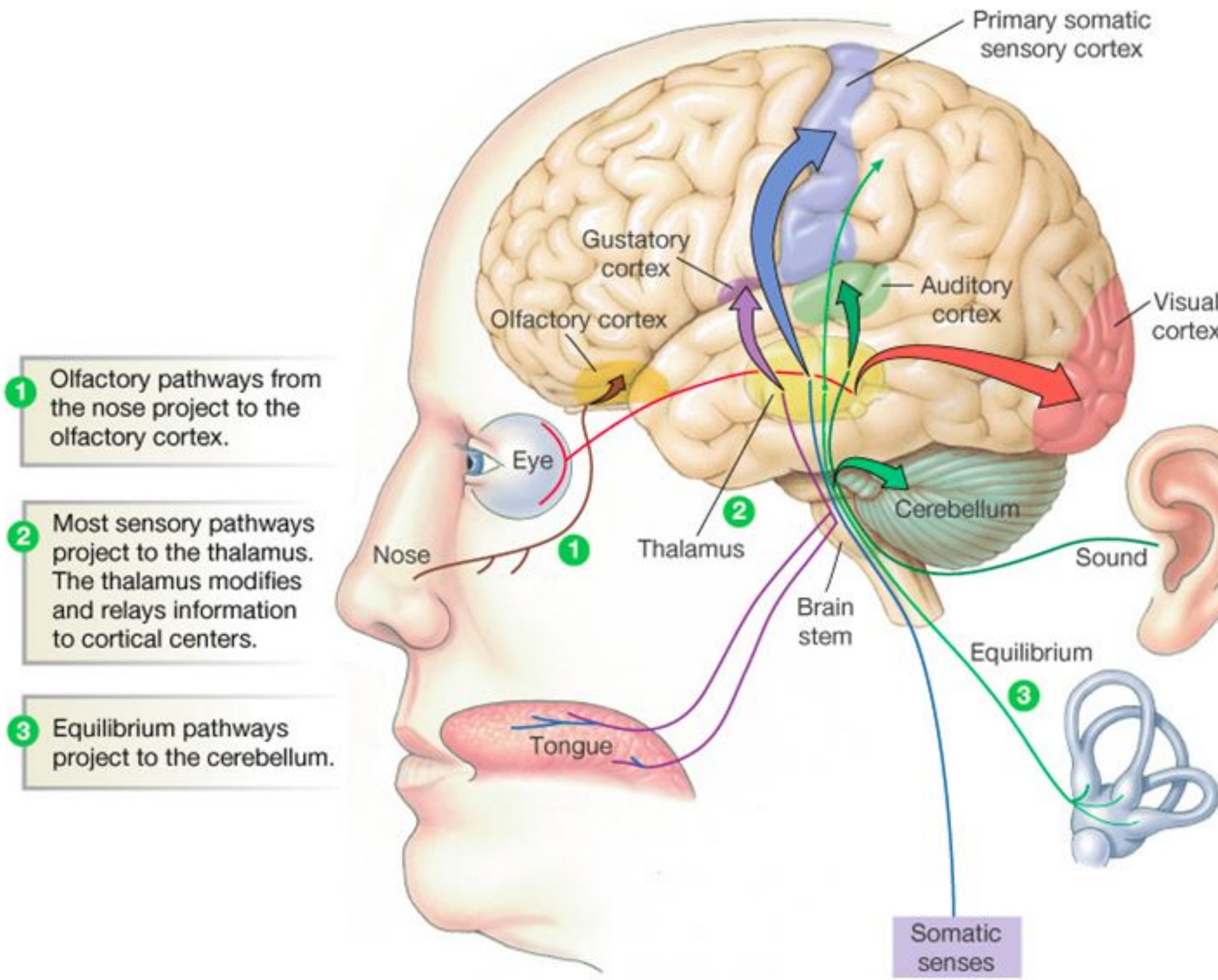


a) A split-brain patient correctly retrieves an object by touch with the left hand when its name is flashed to the right hemisphere, but he cannot name the object or describe what he has done.

b) The word 'hatband' is flashed so that 'hat' goes to the right cerebral hemisphere and 'band' goes to the left hemisphere. The patient reports that he sees the word 'band' but has no idea what kind of band.

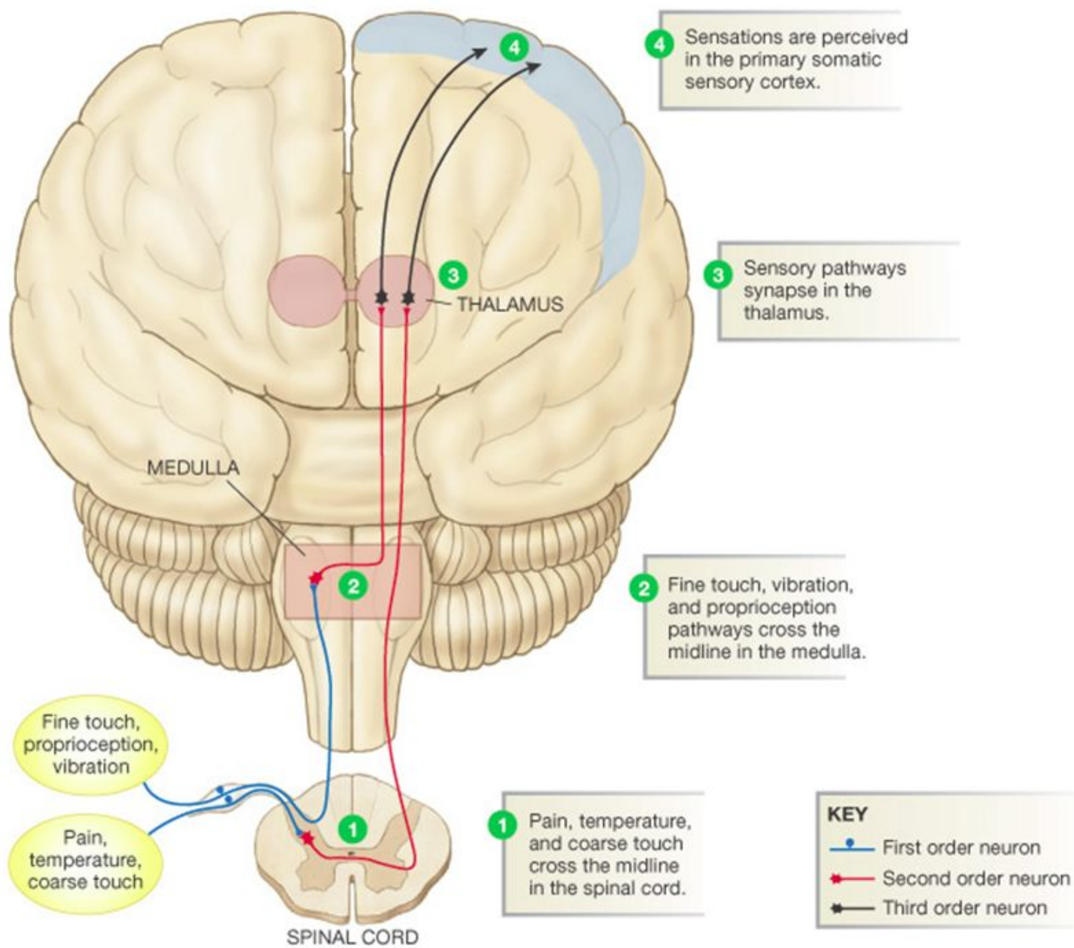
c) A list of common objects (including 'book' and 'cup') is initially shown to both hemispheres. One word from the list ('book') is then projected to the right hemisphere. When given the command to do so, the left hand begins writing the word 'book', but when questioned, the patient does not know what his left hand has written and guesses 'cup'.

Sensory system - special senses



Sensory system - somatic pathway

- Somatosensory stimuli **from below the neck** pass along the sensory pathways of the **spinal cord**, whereas somatosensory stimuli **from the head and neck** travel through **the cranial nerves**



http://faculty.pasadena.edu/dkwon/chap10_A/chap%2010_A%20accessible_files/textmostly/slide8.html

Quiz

What does homonculus correspond to? Is it motor or sensory? how the body is represented in brain? hemispheric specialization? top-down topology?

Studying the brain: methods of inquiry

Studying the brain: methods of inquiry

Name of method	*Procedure*	*Notes*
Selective lesioning	Studying the behavioral consequences of planned and selective lesioning (surgically removing or damaging a structure in the brain)	Only used in animal studies
Single-cell recordings	Studying the activity of single neurons, by probing them with small microelectrodes to discover what stimulus or behavior triggers the cell's activity	Only used in animal studies
Post mortem dissection	Examining patient's brain for lesions (damaged areas) after death	Behavioral consequences must have been studied prior to the death of the patient
Exploratory neurosurgery	Examining patient's brain by electrically stimulating certain areas of the exposed brain	
Event-related potentials (ERPs)	Recording the electrical activity of the brain at the scalp, using electroencephalograms (EEGs), as it occurs in response to a stimulus or preceding a motor response ('event-related')	Gives precise information on the timing of the brain activity, but less precise information on the location (since the recording occurs at the scalp only)
Computerized axial tomography (CAT or CT)	Mapping the brain using X-ray technique	Used to scan the brain for large structural abnormalities
Positron emission tomography (PET)	Measuring brain activity using a radioactive tracer mixed with glucose; active neurons require the most glucose and will be most radioactive	Gives precise information on the location of the brain activity, but less precise information on the timing (since glucose consumption is a relatively slow process)
Functional magnetic resonance imaging (fMRI)	Measuring brain activity by recording magnetic changes resulting from oxygen consumption	Gives precise temporal and spatial information; is relatively expensive
Transcranial magnetic stimulation (TMS)	Examining the consequences of (temporary) disruptions of normal brain functioning caused by magnetic stimulation of small areas	Used to study cognitive functioning
Magnetoencephalography (MEG)	Localizing brain activity by measuring magnetic changes	Precise method used in surgical applications, alongside electrical stimulation of the exposed brain

Studying the brain: methods of inquiry

Selective lesioning	Studying the behavioral consequences of planned and selective lesioning (surgically removing or damaging a structure in the brain)	Only used in animal studies

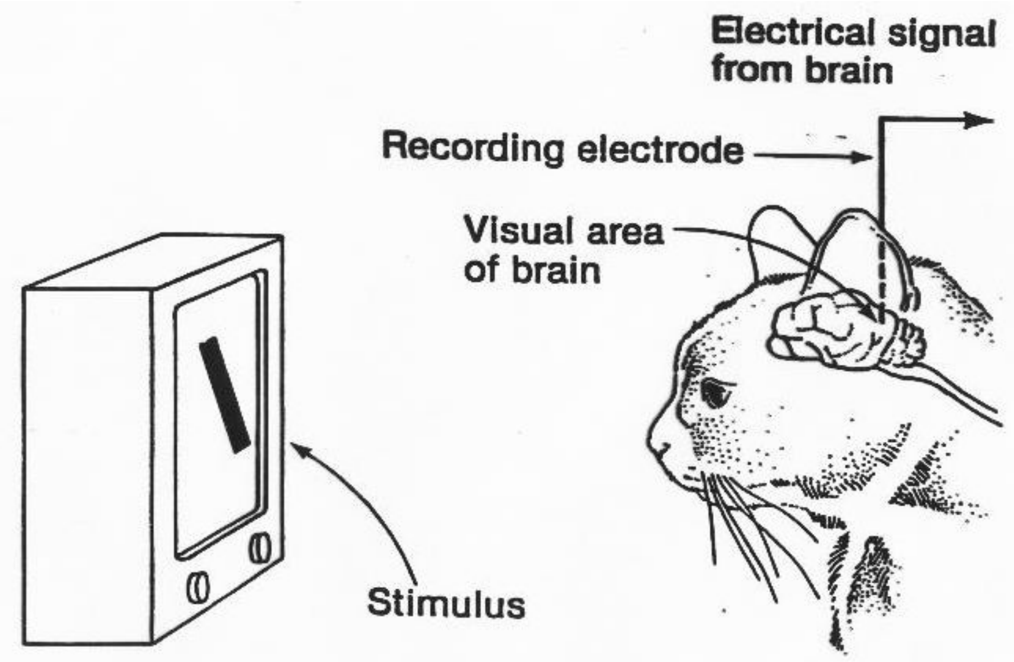
J Pediatr Endocrinol Metab. 2011;24(3-4):131-7.

Studies of different female rat models of hypothalamic obesity.

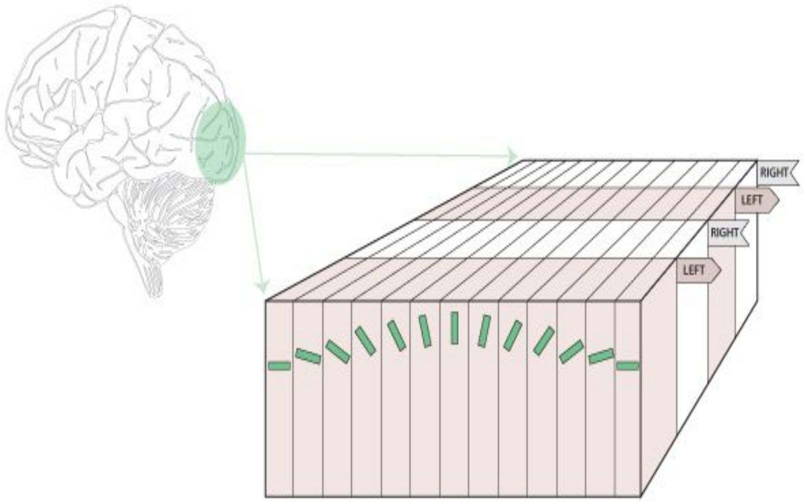
Elfers C[1], Ralston M, Roth CL.

Studying the brain: methods of inquiry

Single-cell recordings	Studying the activity of single neurons, by probing them with small microelectrodes to discover what stimulus or behavior triggers the cell's activity	Only used in animal studies



Hubel and Wiesel (1950)



Video

Cognitive Science in 1950's

- Turing, Alan M. "On computable numbers, with an application to the Entscheidungsproblem." Proceedings of the London mathematical society 2.1 (1937): 230-265.
- McCulloch, W. S., & Pitts, W. (1943). A logical calculus of the ideas immanent in nervous activity. The bulletin of mathematical biophysics, 5(4), 115-133.
- Lettvin, J. Y., Maturana, H. R., McCulloch, W. S., & Pitts, W. H. (1959). What the frog's eye tells the frog's brain. Proceedings of the IRE, 47(11), 1940-1951.
- Hubel, David H., and Torsten N. Wiesel. "Receptive fields of single neurones in the cat's striate cortex." The Journal of physiology 148.3 (1959): 574-591.
- Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. Psychological review, 63(2), 81.
- Newell, Allen, and Herbert Simon. "The logic theory machine--A complex information processing system." IRE Transactions on information theory 2.3 (1956): 61-79.
- Chomsky, Noam. "Three models for the description of language." IRE Transactions on information theory 2.3 (1956): 113-124.
- Von Neumann, John. 1958 The computer and the brain. Yale University Press,.
- Putnam, H. 1960. "Minds and Machines." InS. Hook, ed., Dimensions of Mind. New York: New York University Press.
- Marr, D. (1982) Vision: A Computational Investigation info the Human Representation and Processing of Visual Information. San Francisco: W. H. Freeman.

Studying the brain: methods of inquiry

Exploratory neurosurgery	Examining patient's brain by electrically stimulating certain areas of the exposed brain

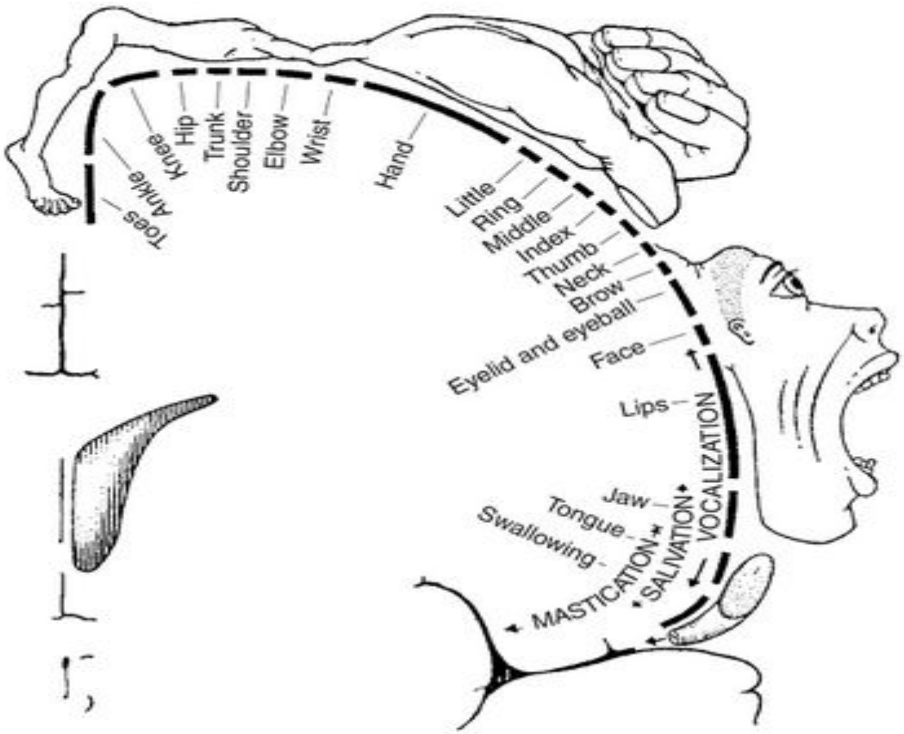
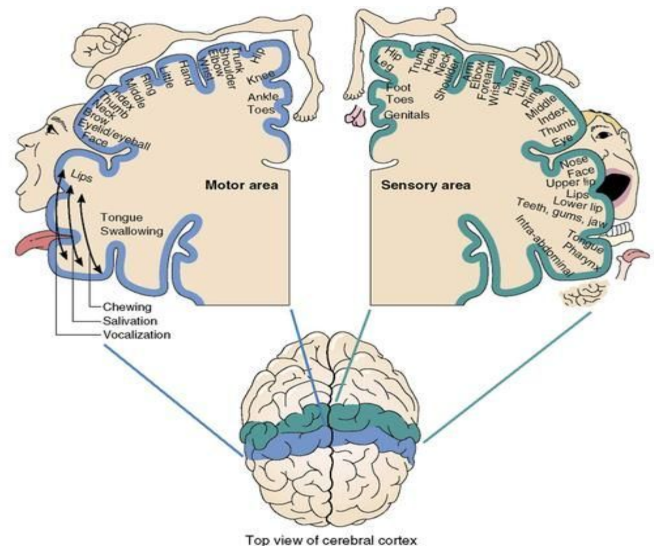


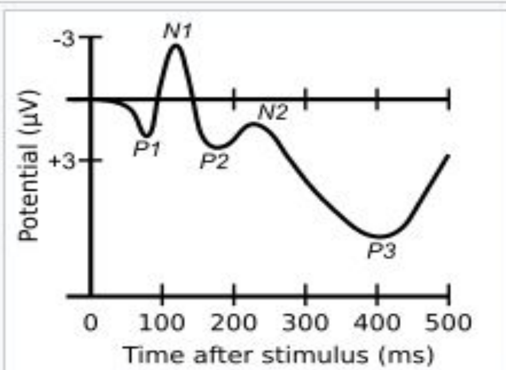
FIGURE 11.18 In the motor homunculus (BA5), muscular control of the mouth, jaw, tongue, vocal cords, as well as actions like chewing and swallowing reside next to Broca's area for the control of speaking (BA 6, 44 and 45). The 'motor homunculus', first discovered by Wilder Penfield using electrical stimulation of motor cortex in awake patients during exploratory neurosurgery (Penfield and Roberts, 1959). Notice that mastication, vocalization and swallowing are marked next to the mouth region of the homunculus. *Source*: Standring, 2005.



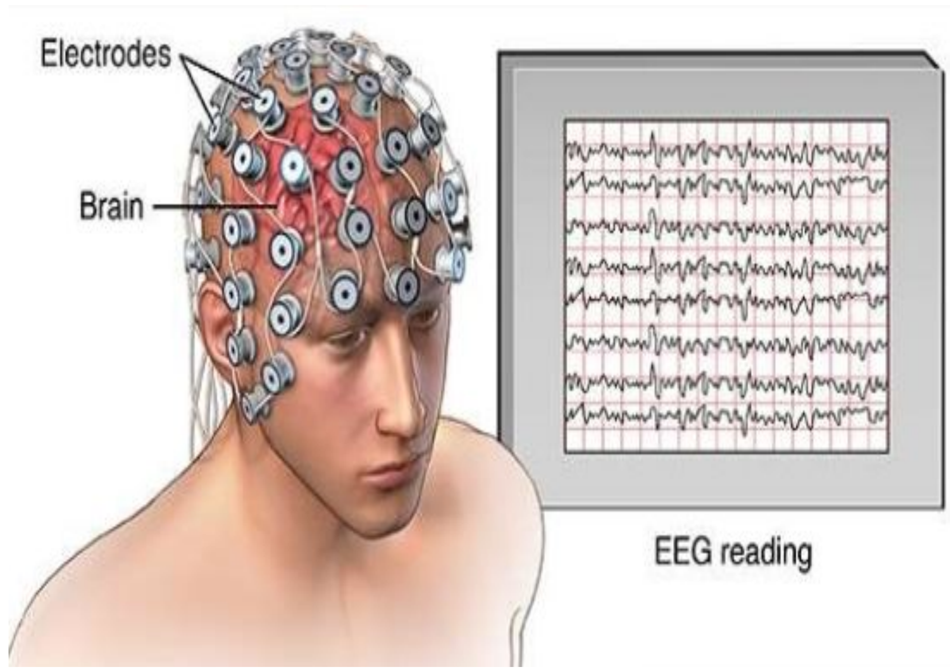
Cognition, Brain, and Consciousness: Introduction to Cognitive Neuroscience By Bernard J. Baars, Nicole M. Gage
https://www.pinterest.at/explore/motor-homunculus/

Studying the brain: methods of inquiry

Event-related potentials (ERPs)	Recording the electrical activity of the brain at the scalp, using electroencephalograms (EEGs), as it occurs in response to a stimulus or preceding a motor response ('event-related')	Gives precise information on the timing of the brain activity, but less precise information on the location (since the recording occurs at the scalp only)

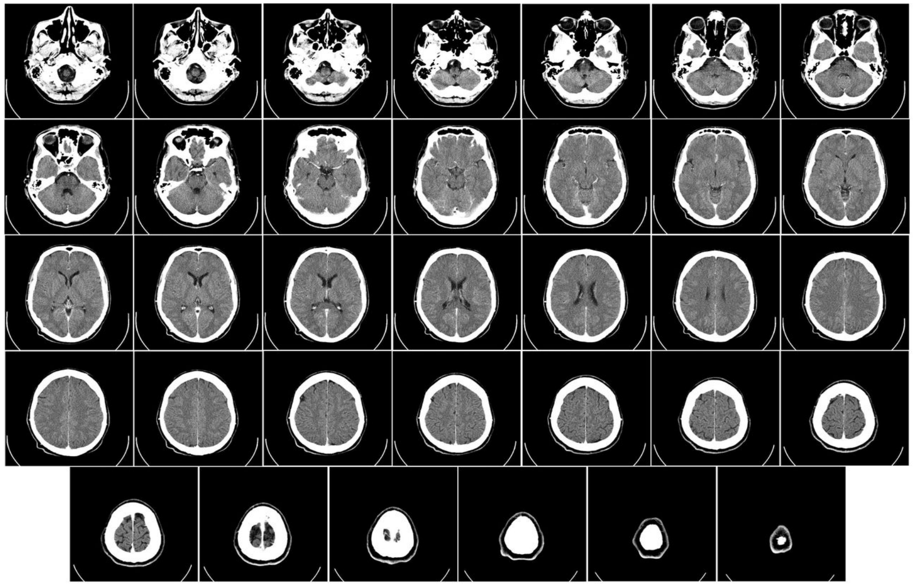


A waveform showing several ERP components, including the N100 and P300. Note that the ERP is plotted with negative voltages upward, a common, but not universal, practice in ERP research



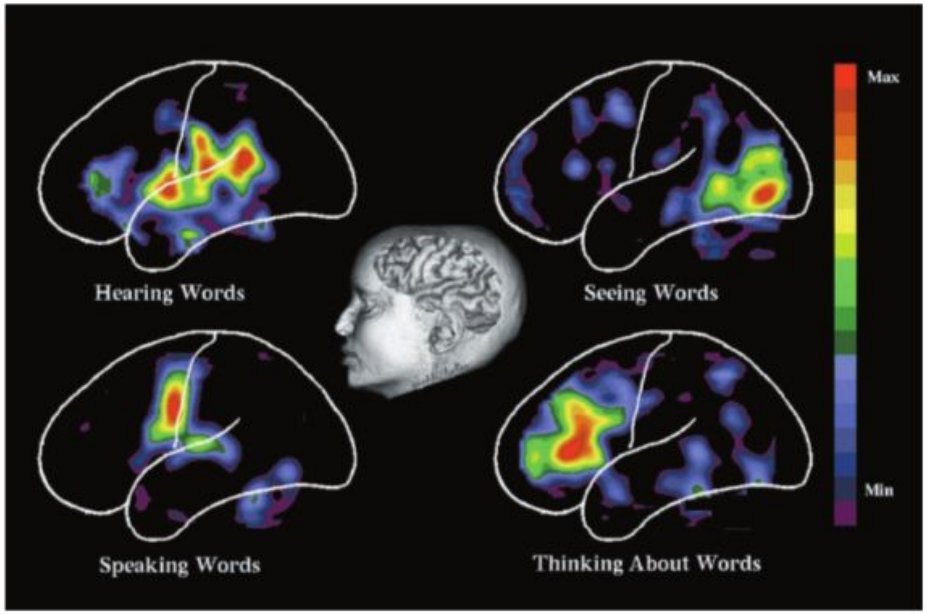
Studying the brain: methods of inquiry

Computerized axial tomography (CAT or CT)	Mapping the brain using X-ray technique	Used to scan the brain for large structural abnormalities



Studying the brain: methods of inquiry

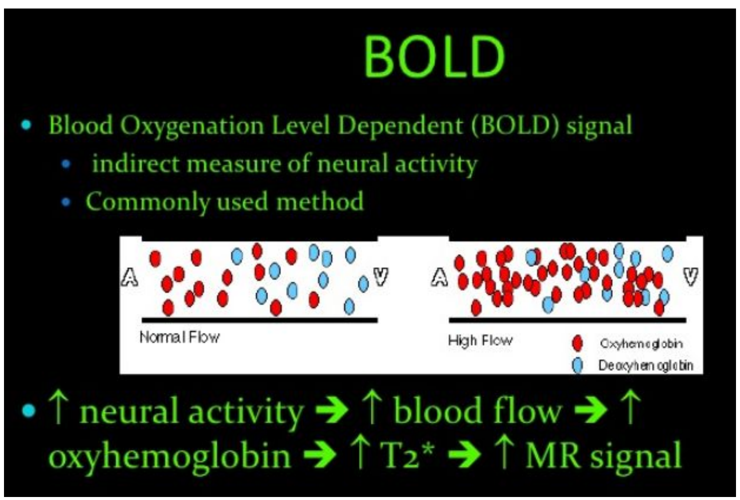
Positron emission tomography (PET)	Measuring brain activity using a radioactive tracer mixed with glucose; active neurons require the most glucose and will be most radioactive	Gives precise information on the location of the brain activity, but less precise information on the timing (since glucose consumption is a relatively slow process)



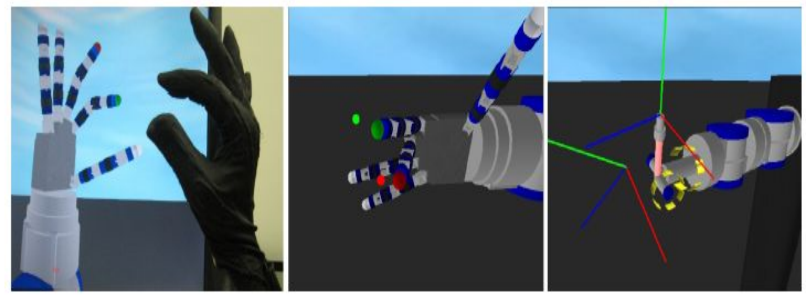
PET scans in a human subject illustrating that different areas of the brain are involved in different modes of word processing.

Studying the brain: methods of inquiry

Functional magnetic resonance imaging (fMRI)	Measuring brain activity by recording magnetic changes resulting from oxygen consumption	Gives precise temporal and spatial information; is relatively expensive



https://www.slideshare.net/ricksw78/fmri-presentation



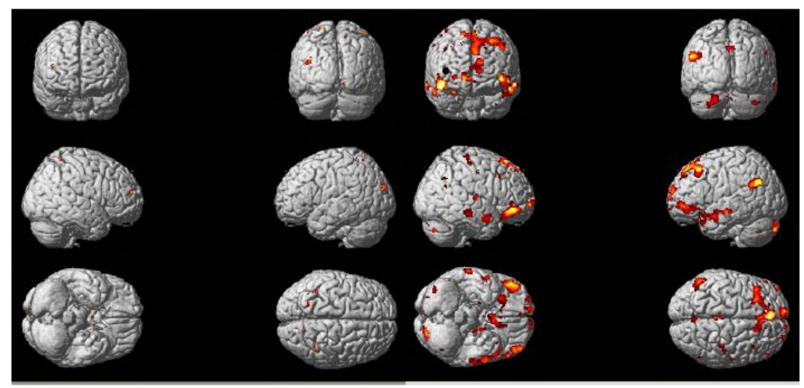
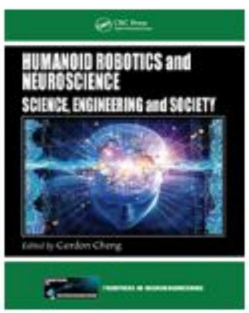


Figure 6. AN-NAN (left) and NAN-AN (right) contrasts for a single subject ($p<0.005$)

Erhan Oztop, Emre Ugur, Yu Shimizu, Hiroshi Imamizu, Humanoid Robotics and Neuroscience: Science, Engineering and Society, 29

Brain activity in use of anthropomorphically similar or dissimilar tools/agents



Humanoid Robotics and Neuroscience: Science, Engineering and Society.

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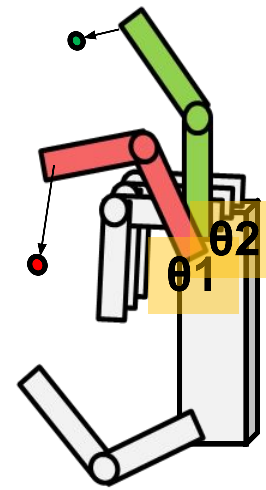
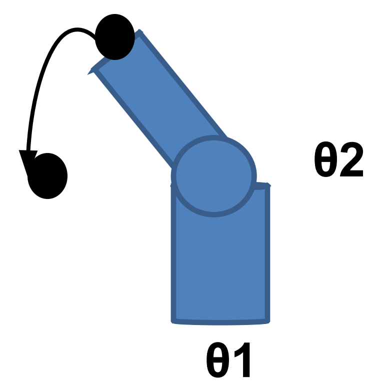
Chapter 2 Humanoid Brain Science

Erhan Oztop, Emre Ugur, Yu Shimizu, and Hiroshi Imamizu.

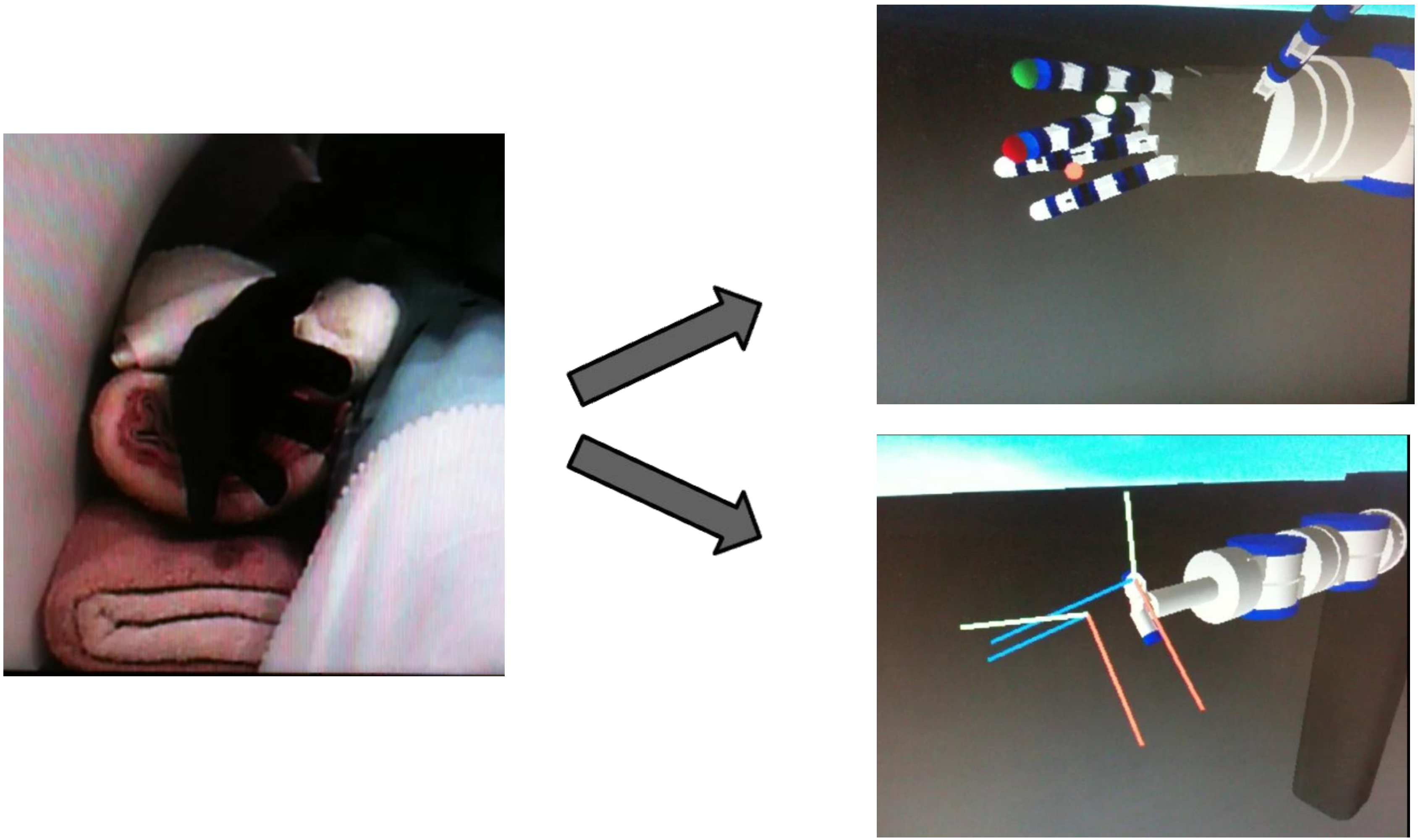
Tool use representation in body-schema?

- **Neural representations** of control of external agents and motor learning mechanisms of **new tools**.
- Hypothesis:
  - Robots anthropomorphically similar to human body became **part of our body schema**
  - Whereas non-anthropomorphic robots induce **internal model formation** in other parts of the brain.
- Expect differences in fMRI activation.

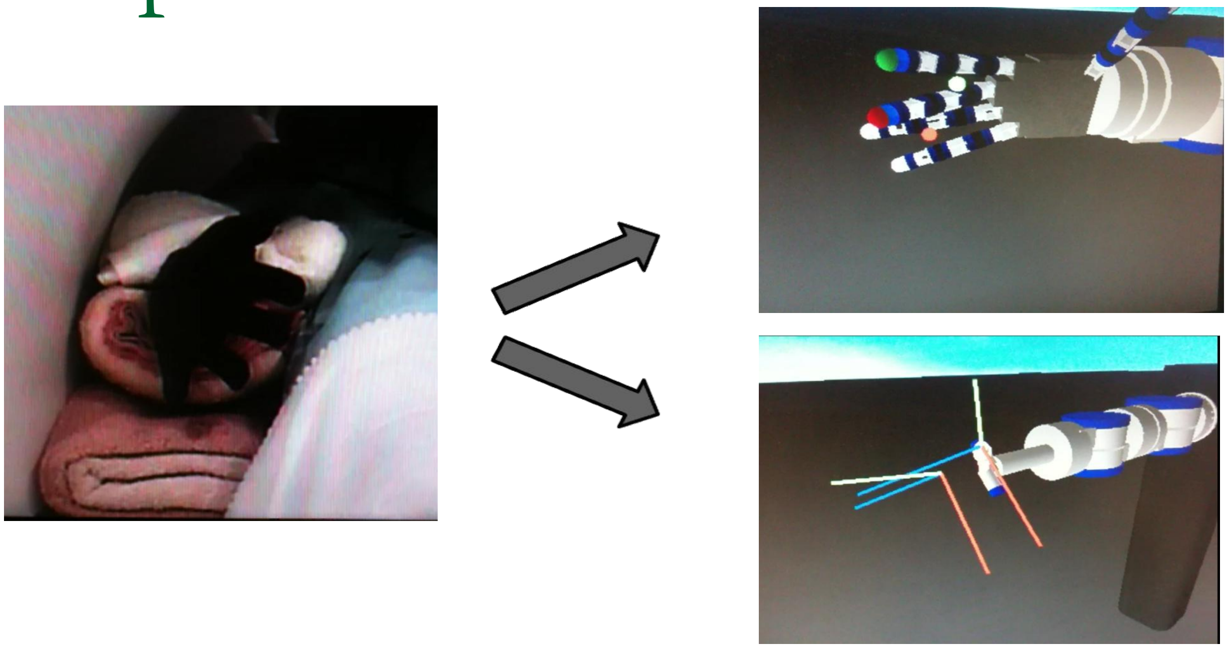




Anthropomorphic tools fMRI experiment



Anthropomorphic tools
fMRI experiment



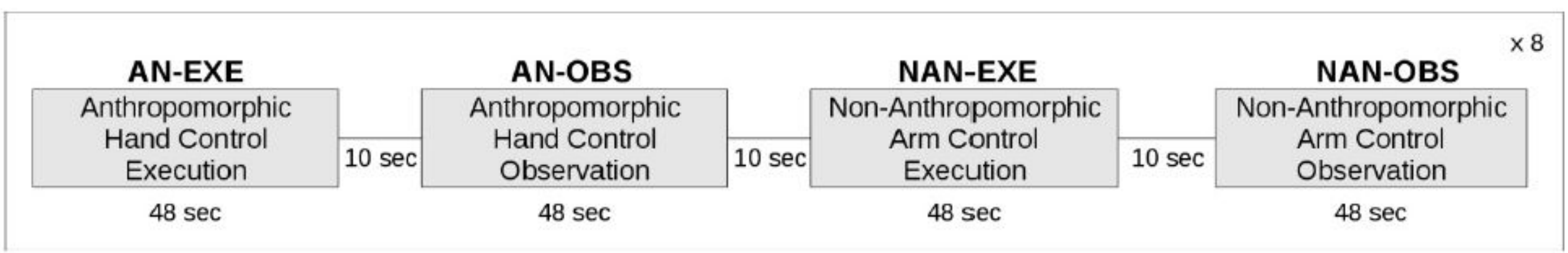


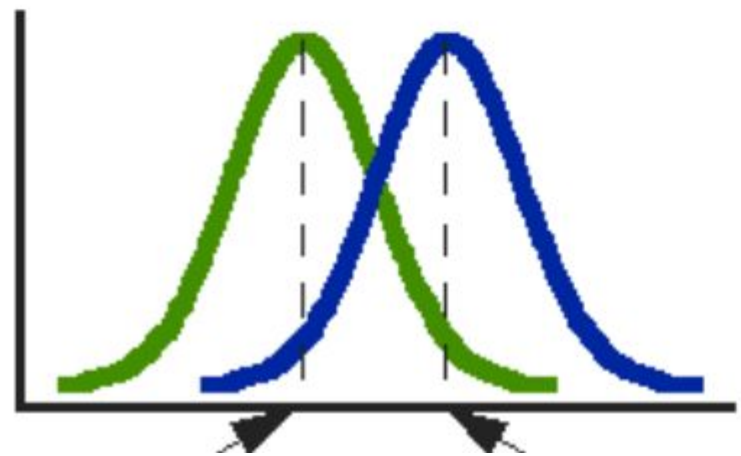
Figure 7. The experimental paradigm. Anthropomorphic and non-anthropomorphic control corresponds to hand and arm control, respectively. In the visual blocks, the subjects do not move, but watch a recording of the previous execution block including the robot movements.

Anthropomorphic (AN, hand) vs Non-anthropomorphic (NAN, arm)

- Question: What are the mechanism behind control and learning?
- Hypothesis: AN and NAN are represented in different regions
  - AN: becomes part of body schema – parietal cortex
  - NAN: external model – cerebellum
- Which control conditions should be kept fixed?

Significant difference in performance between hand and arm control?

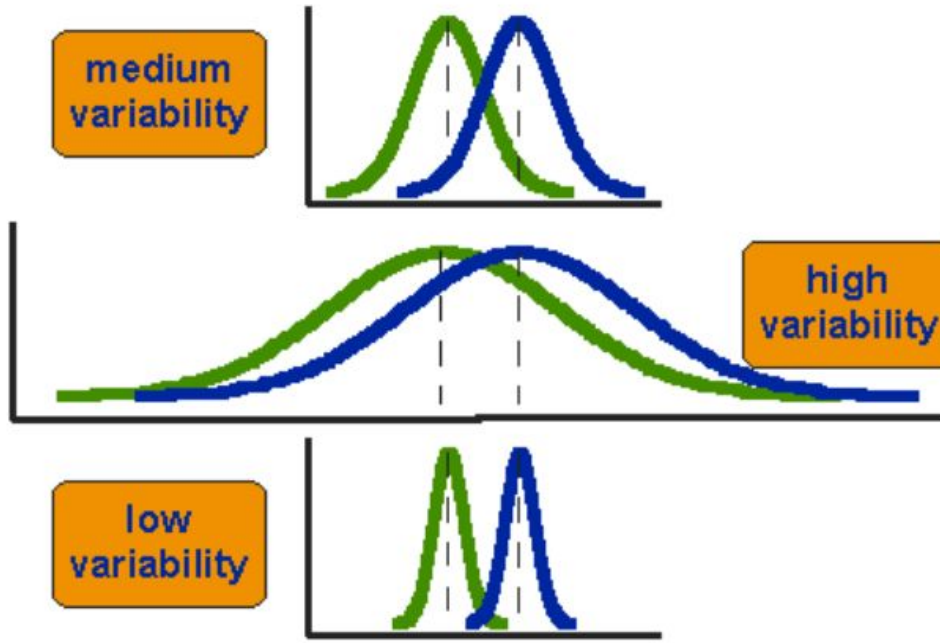
- The t-test assesses whether the means of two groups are statistically different from each other.



- Performance distributions of
  - Green: Robot control
  - Blue: Hand control
- From 2 executions?
- 2000 executions
- Number of sample counts!

Significant difference in performance between hand and arm control?

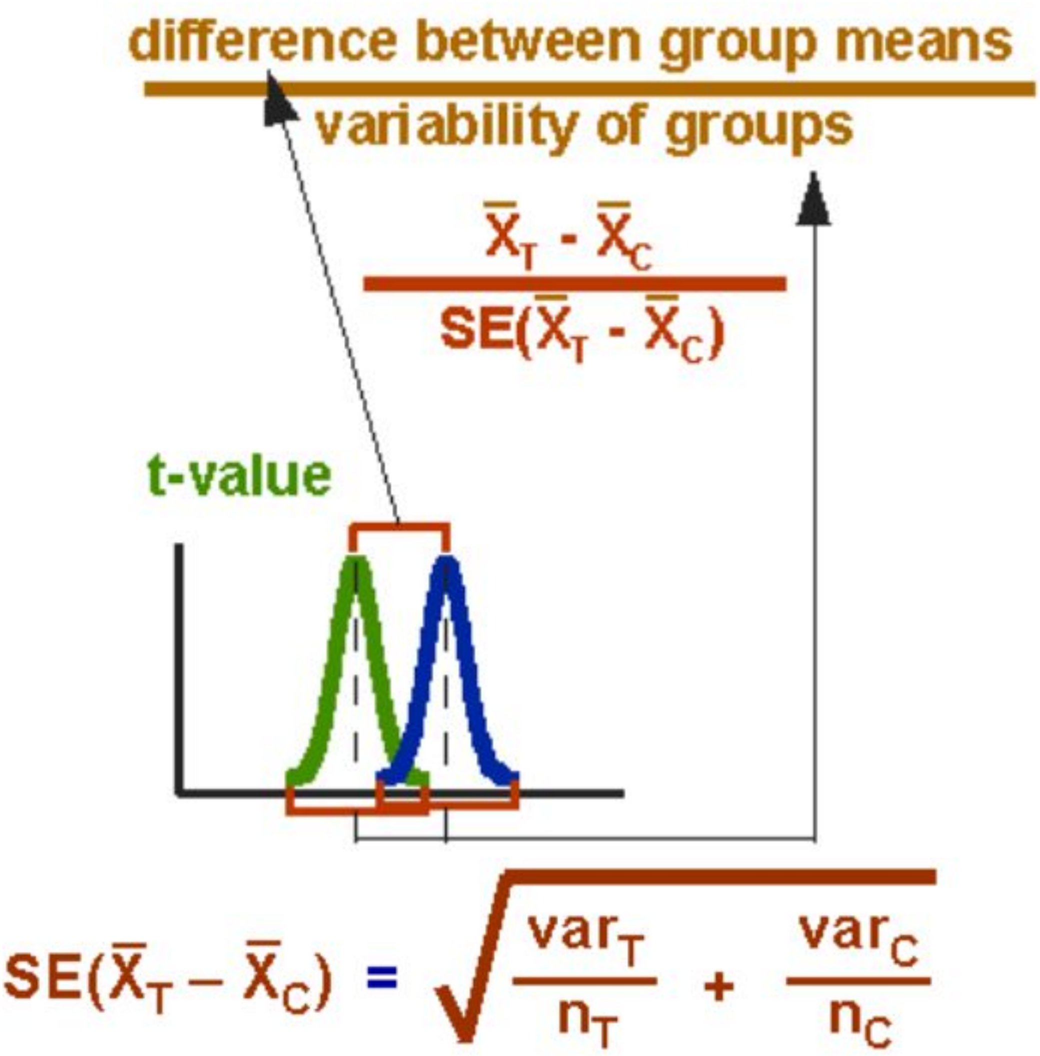
- The difference between the means is the same in all three.
- two groups appear most different or distinct
  - Where?
  - Why?



- Judge the difference between their means relative to the spread or variability of their scores.

Significant difference in performance between hand and arm control?

- t value boils down all of your sample data down to one value, the t-value
  - means, variances, number of samples
- Sign matters?
- look it up in a table of significance



Significant difference in performance between hand and arm control?

	a1	a2
	5	13
	3	9
	4	10
	4	8
	6	9
	1	12
	3	8
	4	12
	6	10
	4	9
Sum(A)	40	100
Sum of squares	180	1028

$$\sigma_{diff} = \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}} = \sqrt{\frac{2.22}{10} + \frac{3.11}{10}} = .73$$

$$t = \frac{\mu_{a1} - \mu_{a2}}{\sigma_{diff}} = \frac{-6}{.73} = -8.22$$

Significant difference in performance between hand and arm control?

- Critical values of the t-test

One Sided	**75%**	**80%**	**85%**	**90%**	**95%**	**97.5%**	**99%**	**99.5%**	**99.75%**	**99.9%**	**99.95%**
Two Sided	**50%**	**60%**	**70%**	**80%**	**90%**	**95%**	**98%**	**99%**	**99.5%**	**99.8%**	**99.9%**
1	1.000	1.376	1.963	3.078	6.314	12.71	31.82	63.66	127.3	318.3	636.6
2	0.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	14.09	22.33	31.60
10	0.700	0.879	1.093	1.372	1.812	2.228	2.764	3.169	3.581	4.144	4.587
11	0.697	0.876	1.088	1.363	1.796	2.201	2.718	3.106	3.497	4.025	4.437
16	0.690	0.865	1.071	1.337	1.746	2.120	2.583	2.921	3.252	3.686	4.015
17	0.689	0.863	1.069	1.333	1.740	2.110	2.567	2.898	3.222	3.646	3.965
18	0.688	0.862	1.067	1.330	1.734	2.101	2.552	2.878	3.197	3.610	3.922
19	0.688	0.861	1.066	1.328	1.729	2.093	2.539	2.861	3.174	3.579	3.883
20	0.687	0.860	1.064	1.325	1.725	2.086	2.528	2.845	3.153	3.552	3.850
21	0.686	0.859	1.063	1.323	1.721	2.080	2.518	2.831	3.135	3.527	3.819
22	0.686	0.858	1.061	1.321	1.717	2.074	2.508	2.819	3.119	3.505	3.792
23	0.685	0.858	1.060	1.319	1.714	2.069	2.500	2.807	3.104	3.485	3.767
24	0.685	0.857	1.059	1.318	1.711	2.064	2.492	2.797	3.091	3.467	3.745

Significant difference in performance between hand and arm control?

- Critical values for t-test

Probability less than the critical value ($t_{1-\alpha,\nu}$)

ν	0.90	0.95	0.975	0.99	0.995	0.999
1.	3.078	6.314	12.706	31.821	63.657	318.313
2.	1.886	2.920	4.303	6.965	9.925	22.327
3.	1.638	2.353	3.182	4.541	5.841	10.215
4.	1.533	2.132	2.776	3.747	4.604	7.173
5.	1.476	2.015	2.571	3.365	4.032	5.893
6.	1.440	1.943	2.447	3.143	3.707	5.208
7.	1.415	1.895	2.365	2.998	3.499	4.782
8.	1.397	1.860	2.306	2.896	3.355	4.499
9.	1.383	1.833	2.262	2.821	3.250	4.296
10.	1.372	1.812	2.228	2.764	3.169	4.143
11.	1.363	1.796	2.201	2.718	3.106	4.024
12.	1.356	1.782	2.179	2.681	3.055	3.929
13.	1.350	1.771	2.160	2.650	3.012	3.852
14.	1.345	1.761	2.145	2.624	2.977	3.787
15.	1.341	1.753	2.131	2.602	2.947	3.733
16.	1.337	1.746	2.120	2.583	2.921	3.686
17.	1.333	1.740	2.110	2.567	2.898	3.646
18.	1.330	1.734	2.101	2.552	2.878	3.610
19.	1.328	1.729	2.093	2.539	2.861	3.579
20.	1.325	1.725	2.086	2.528	2.845	3.552

Sample question: Calculate a paired t test by hand for the following data:

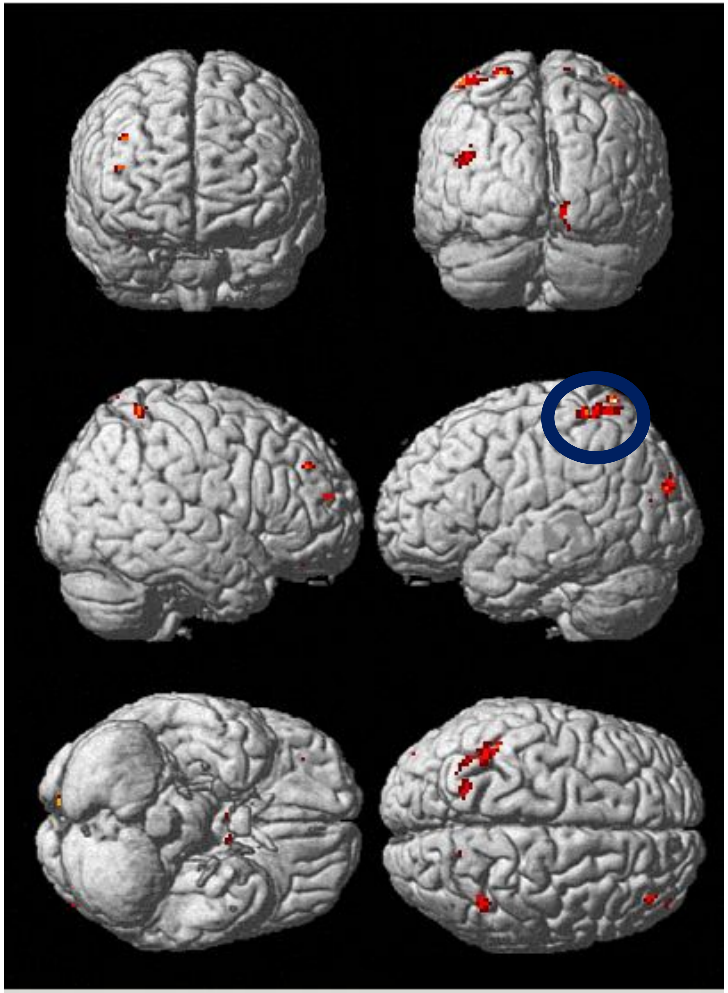
Subject #	Score 1	Score 2
1	3	20
2	3	13
3	3	13
4	12	20
5	15	29
6	16	32
7	17	23
8	19	20
9	23	25
10	24	15
11	32	30

$$t = \frac{-73/11}{\sqrt{\dfrac{1131 - \left(\dfrac{5329}{11}\right)}{110}}}$$

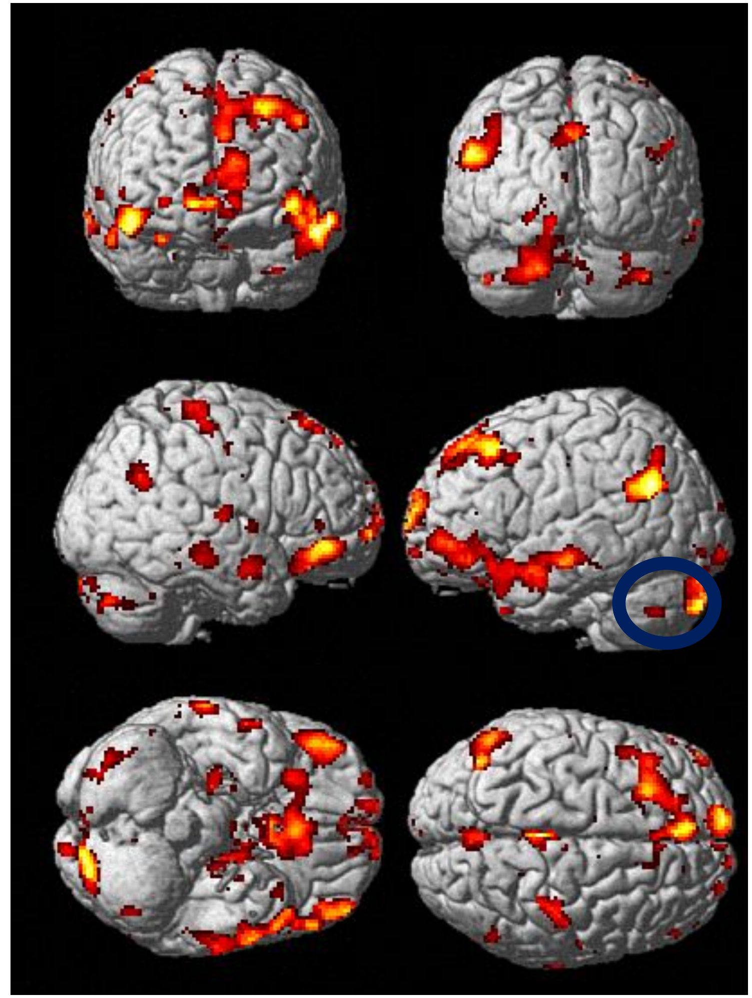
$$t = -\ 2.74$$

DF	A = 0.2	0.10	0.05	0.02	0.01	0.002
∞	t_a = 1.282	1.645	1.960	2.326	2.576	3.091
1	3.078	6.314	12.706	31.821	63.656	318.289
2	1.886	2.920	4.303	6.965	9.925	22.328
3	1.638	2.353	3.182	4.541	5.841	10.214
4	1.533	2.132	2.776	3.747	4.604	7.173
5	1.476	2.015	2.571	3.365	4.032	5.894
6	1.440	1.943	2.447	3.143	3.707	5.208
7	1.415	1.895	2.365	2.998	3.499	4.785
8	1.397	1.860	2.306	2.896	3.355	4.501
9	1.383	1.833	2.262	2.821	3.250	4.297
10	1.372	1.812	2.228	2.764	3.169	4.144
11	1.363	1.796	2.201	2.718	3.106	4.025

Anthropomorphic tools fMRI results



AN > NAN



NAN > AN

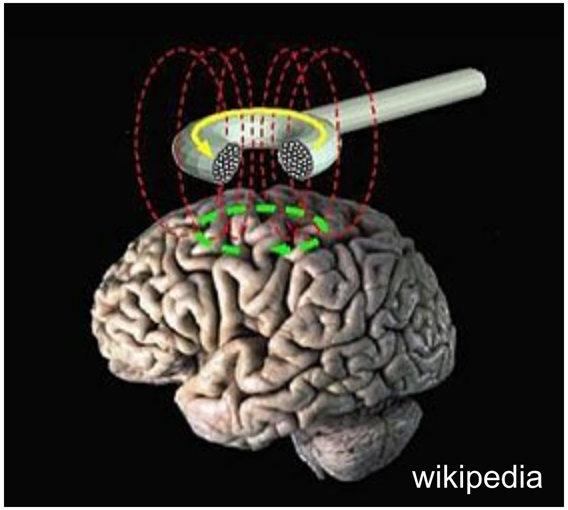
T-statistics were used for comparison of the
estimated parameters of AN=(AN-EXE – AN-OBS) and NAN=(NAN-EXE – NAN-OBS). Two contrasts of AN –NAN and NAN – AN then yielded a t-value for each voxel. A threshold of P< 0.005 was used in obtaining the activation maps shown in this chapter.

Anthropomorphic tools fMRI results

- **High prefrontal activation** in the NAN-AN contrast indicates task difficulty in the NAN condition.
- NAN condition engaged the **angular gyrus**, which is involved in detection of mismatch between intended and actual movement leading to a loss of “action ownership” (agency)
- **Superior parietal regions** are involved in programming the movement according to extrinsic spatial information . The activation in this region suggests that the subject controlled the robot fingers as if they were the subject’s own fingers, thereby supporting the hypothesis that the hand robot was incorporated into the body schema
- The **occipital activity** in the AN-NAN contrasts may reflect the necessary fine control around the target points, which relies on detailed visual information

Studying the brain: methods of inquiry

Transcranial magnetic stimulation (TMS)	Examining the consequences of (temporary) disruptions of normal brain functioning caused by magnetic stimulation of small areas	Used to study cognitive functioning



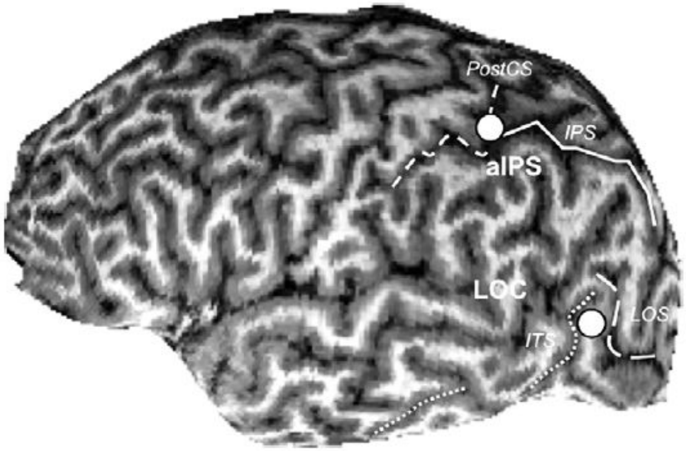
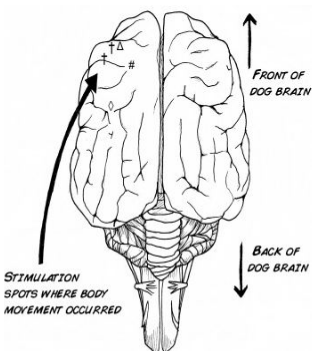


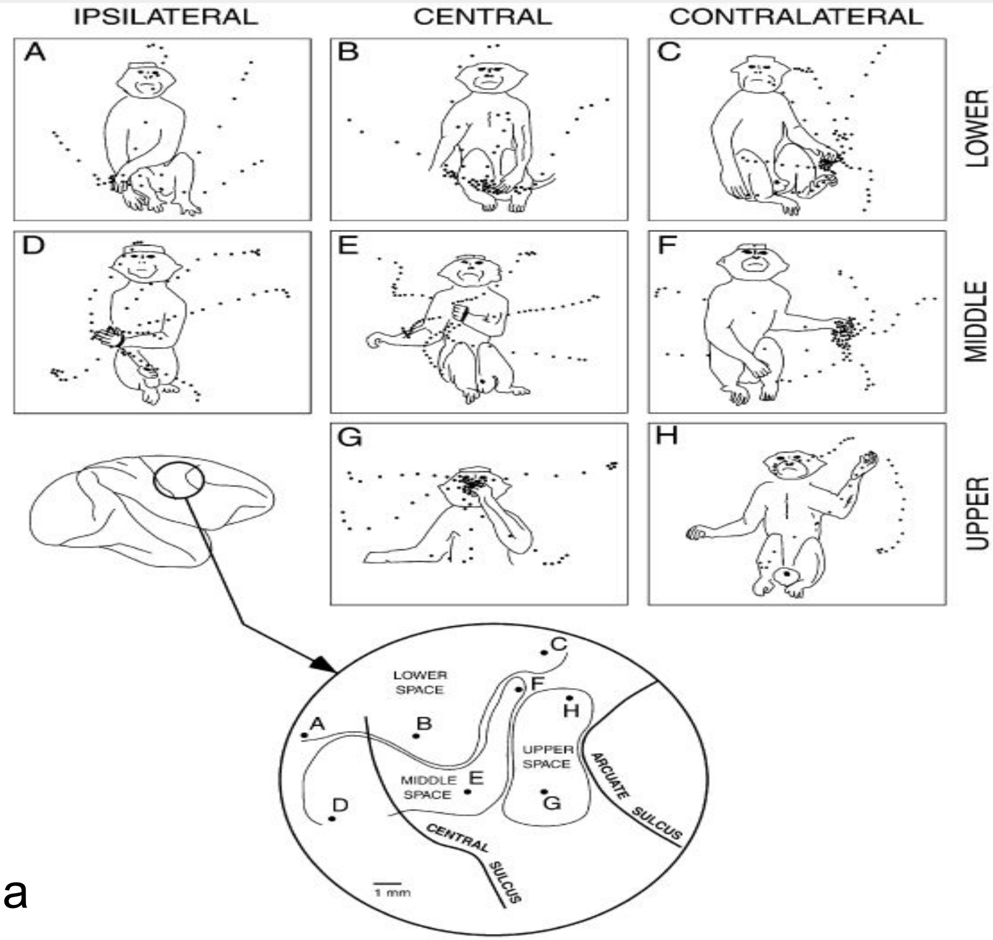
Fig. 2. Localization of brain sites for TMS. A three dimensional rendering of one subject's structural MRI in Brainsight, illustrating the cortical sites chosen for stimulation, as indicated by the white dots: (1) the anterior intraparietal sulcus, aIPS, site was located at the junction of the anterior intraparietal sulcus, (IPS, solid line), and the postcentral sulcus (PostCS, dashed line); (2) the lateral occipital, LO, site was near the junction of the inferior temporal sulcus (ITS, fine-dashed line) and lateral occipital sulcus (LOS, coarse-dashed line). Area MT+ lies at the junction of the two sulci (Dumoulin et al., 2000) and intersubject comparisons of MT+ and LO foci from an fMRI study (data provided by Tutis Vilis; see also Large, Aldcroft, & Vilis, 2005,

Ventral and dorsal stream contributions to the online control of immediate and delayed grasping: a TMS approach NR Cohen, ES Cross, E Tunik, ST Grafton, JC Culham - Neuropsychologia, 2009

Studying the brain: methods of inquiry

Microstimulation



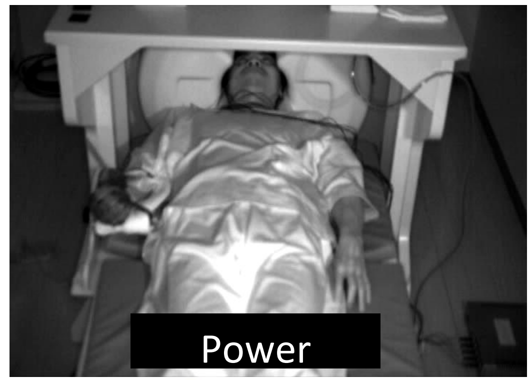


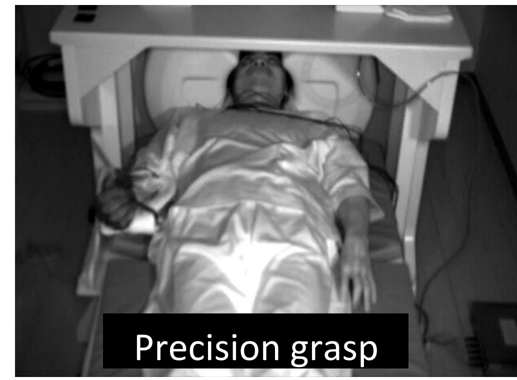
- Eduard Hitzig and Gustav Fritsch (1870)
  - the interaction between electric current and the brain.
  - electricity via a thin probe to the exposed cerebral cortex of a dog without anesthesia.
  - Identified the brain's "motor strip", a vertical strip of brain tissue on the cerebrum in the back of the frontal lobe

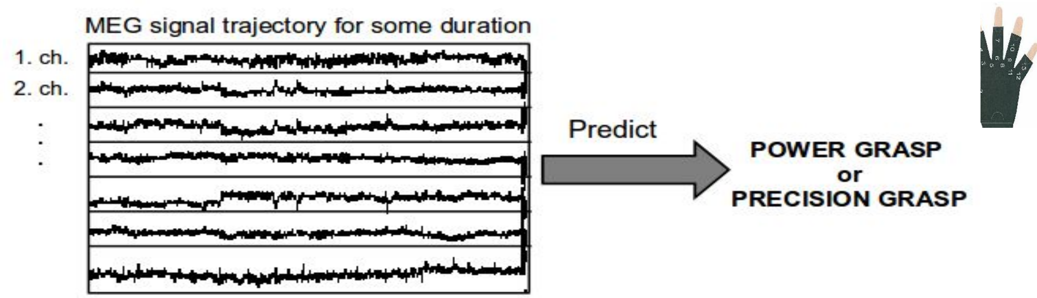
Complex movements evoked by microstimulation of precentral cortex MSA Graziano, CSR Taylor, T Moore - Neuron, 2002 - Elsevier

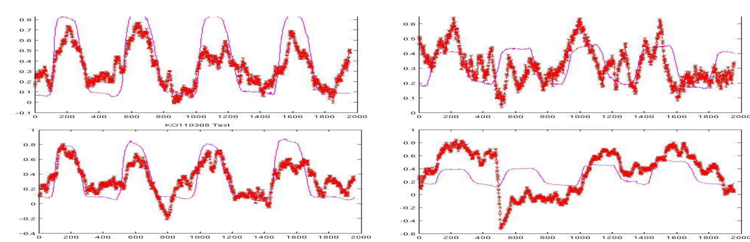
Studying the brain: methods of inquiry

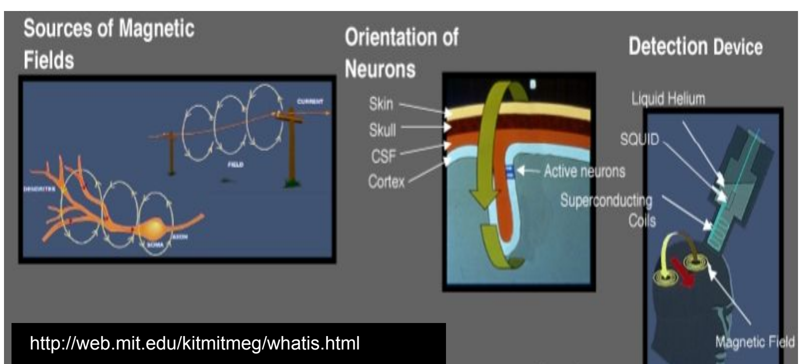
Magnetoencephalography (MEG)	Localizing brain activity by measuring magnetic changes	Precise method used in surgical applications, alongside electrical stimulation of the exposed brain











E. Ugur, Y. Shimizu, E. Oztop, and H. Imamizu, Reconstruction of Grasp Posture from MEG Brain Activity, The 34th Annual Meeting of the Japan Neuroscience Society, Yokohama, Japan, 2011.

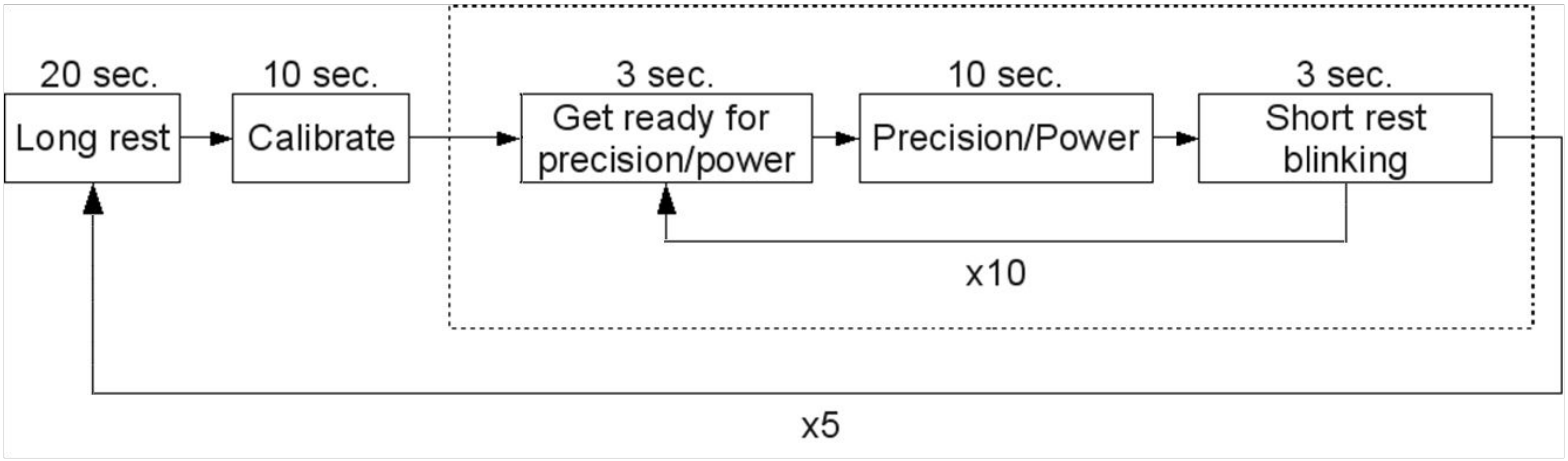
Results on grasp decoding using MEG

E. UGUR, Y. SHIMIZU, E. OZTOP, AND H. IMAMIZU,
Reconstruction of Grasp Posture from MEG Brain Activity, The 34th Annual Meeting of the Japan Neuroscience Society, Yokohama, Japan, 2011.

Grasp decoding using MEG

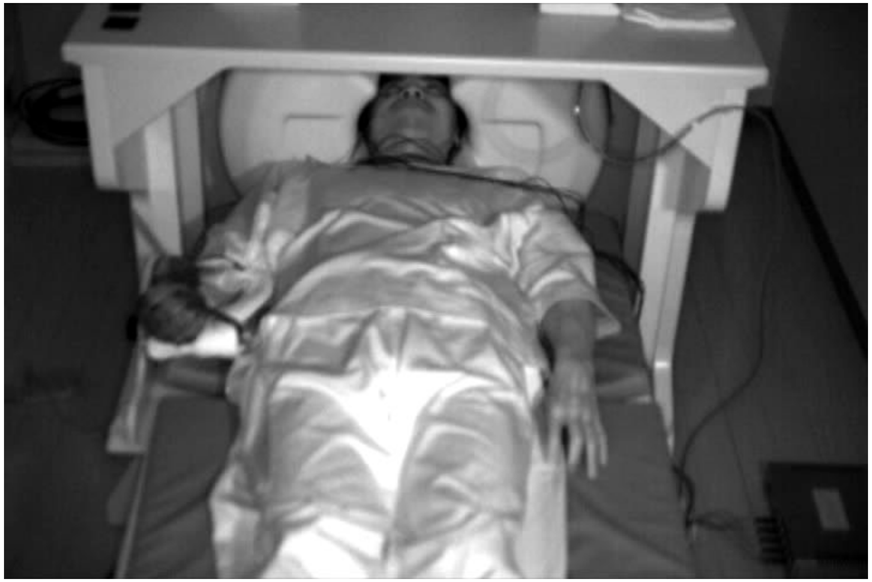
- We aim at both
  - decoding the grasp type (power or precision), and
  - reconstructing the aperture size based on MEG signals

Experimental Setup



- fMRI compatible data glove gets real joint angles
- Experiment details:
  - 1st and 2nd sessions: 5x10 blocks with usual hand orientation
  - 3rd session: 5x10 blocks with rotated hand orientation
- 200 Hz: 2000 data points in each block
- Only axial sensors are used

Experimental Setup



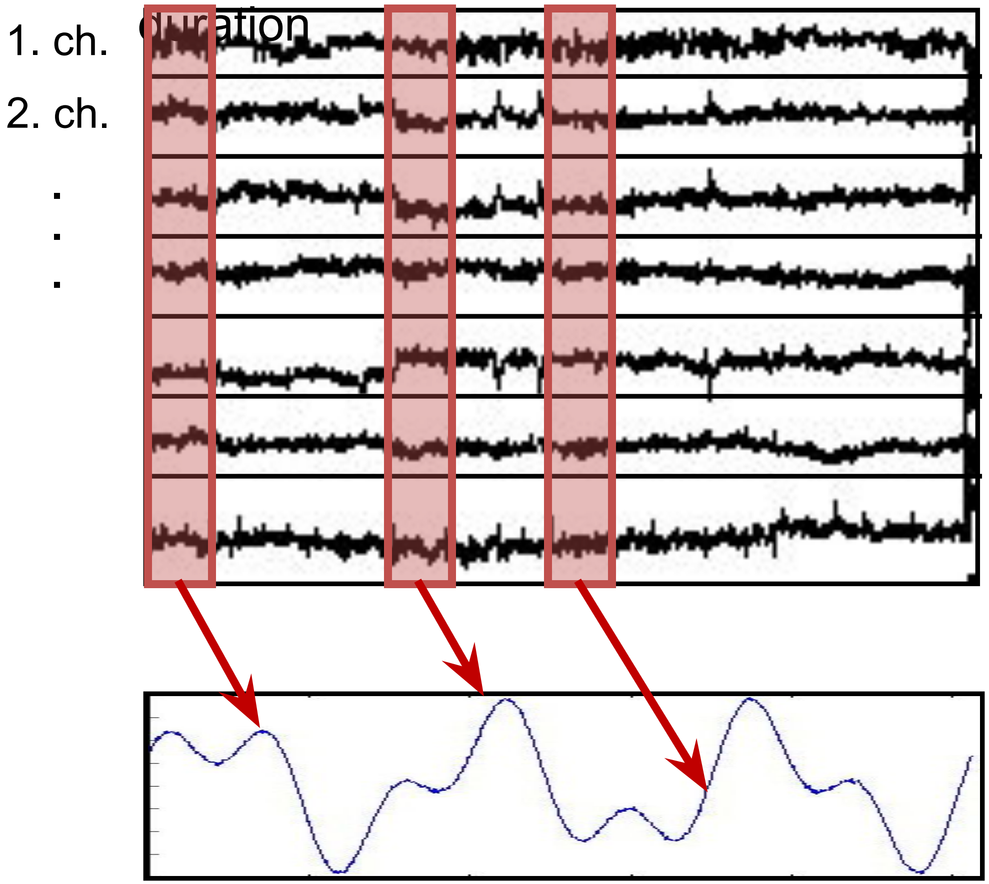
Power grasp

Precision grasp

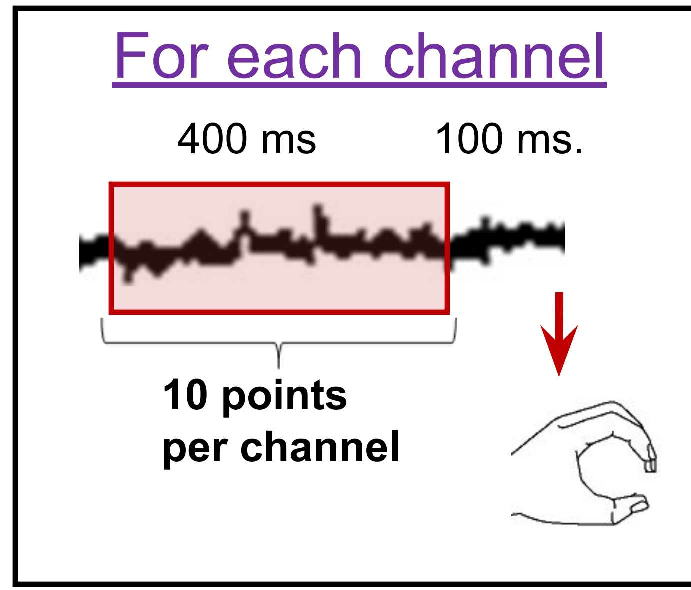
- Record joint angles using data glove
- Compute aperture size from joint angl
  - Power-grasp: mean(3,6,9,12)
  - Precision-grasp: mean (3,6)

Reconstruct aperture size

MEG signal trajectory for some duration



Grasp aperture or any joint angle

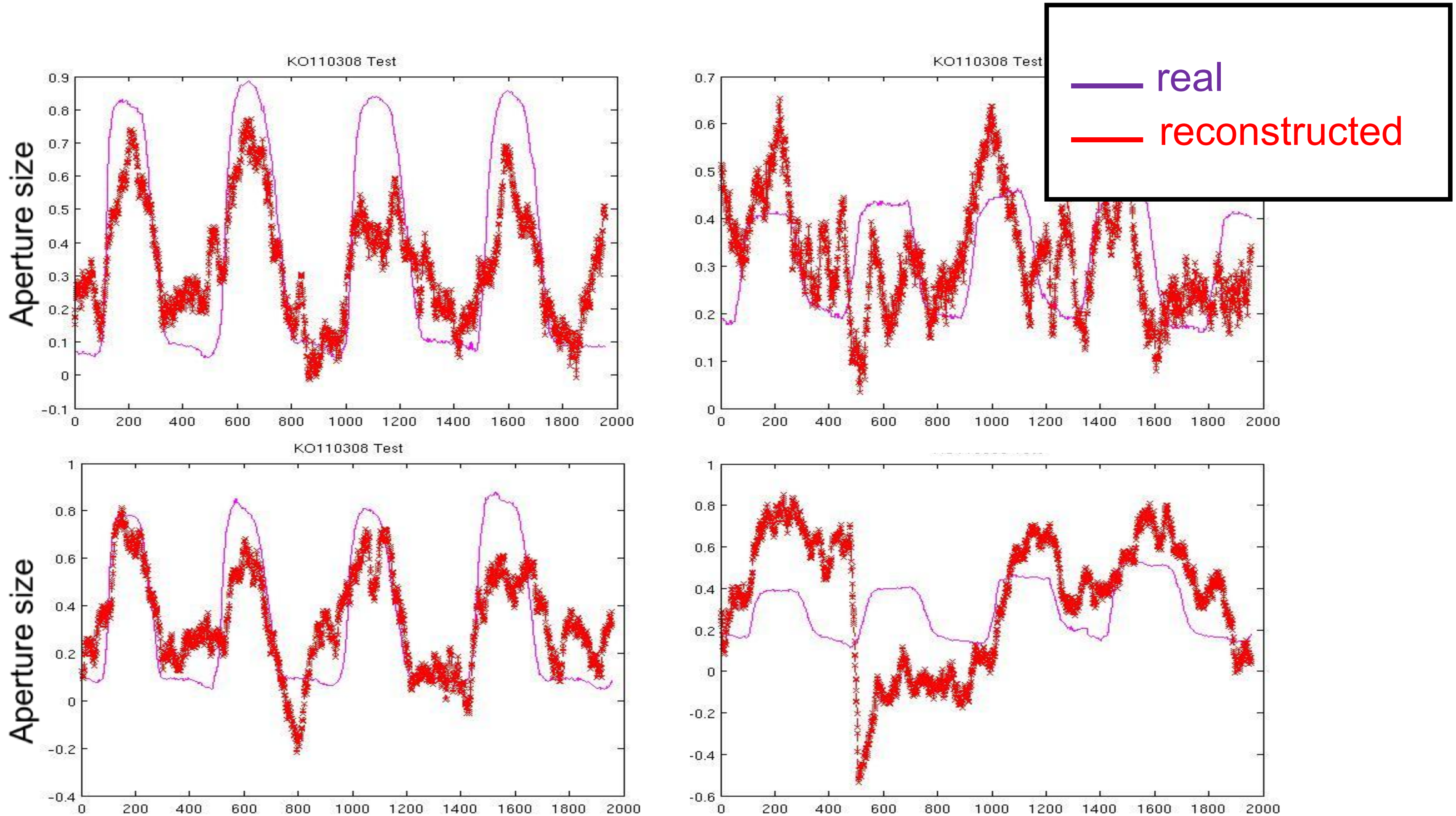


Sparse Linear Regression
(Sato et al. (2001) etc.)

# of features = C x 10

where C is # of channels

Aperture reconstruction with power + precision combined



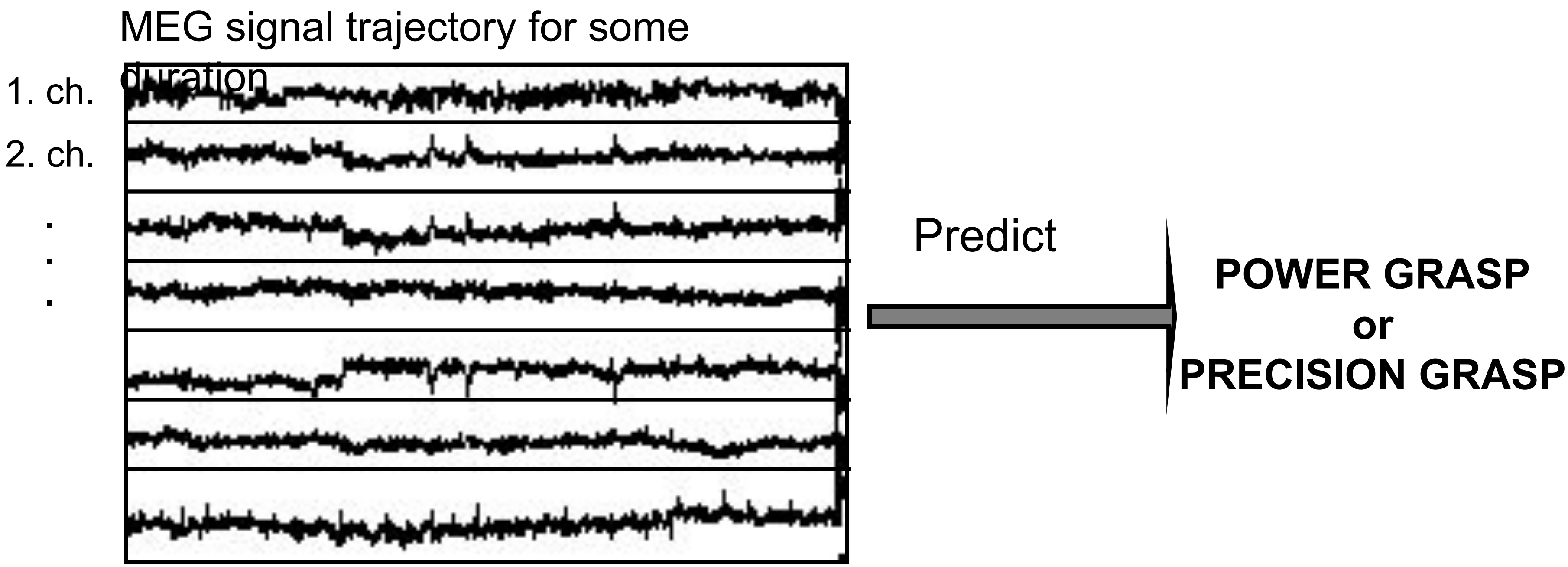
Sample power grasp trajectories

Sample precision grasp trajectories

Two step reconstruction

- Step 1: Make classification
  - Decide whether power or precision grasp in the beginning
- Step 2: Regress for each grasp type separately
  - Reconstruct based on its predicted grasp class

Step 1: Prediction of grasp type



Step 1: Prediction of grasp type

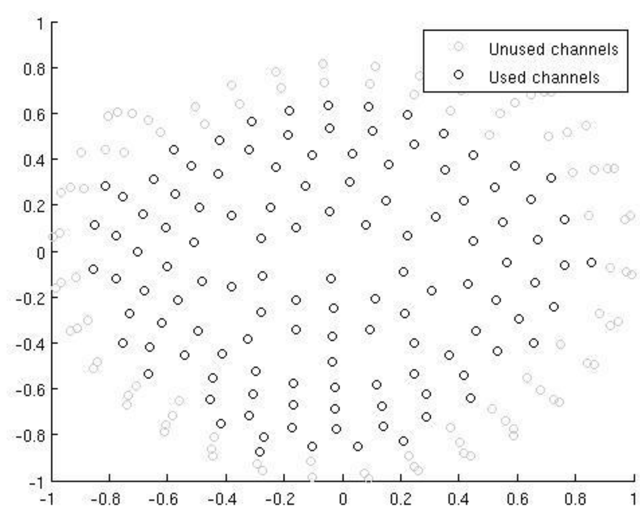
Features that represent statistics of MEG signal trajectory

1. ch.	(Mean, std. dev., coherence) in freq. band. X-Y (Mean, std. dev., coherence) in freq. band. Y-Z
2. ch.	(Mean, std. dev., coherence) in freq. band. X-Y (Mean, std. dev., coherence) in freq. band. Y-Z
119. ch.	(Mean, std. dev., coherence) in freq. band. X-Y (Mean, std. dev., coherence) in freq. band. Y-Z

Classify

POWER GRASP
or
PRECISION GRASP

- Train SVM
  - Feature number: (3 x 2 x 119)



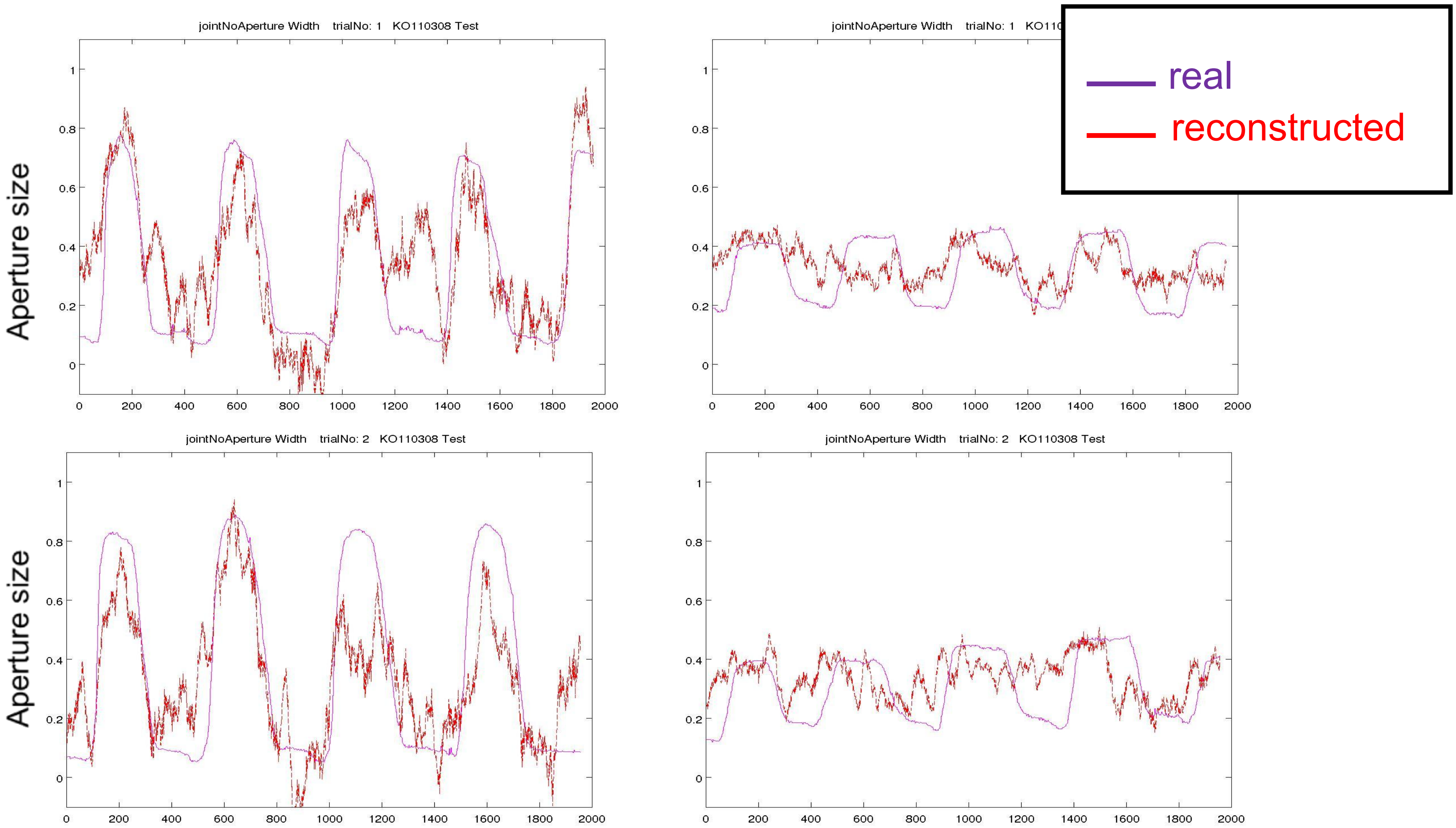
Classification Results

Duration	SVM kernel	Same session	Same hand orientation	Different hand orientation
0-10 sec	RBF	78 %	62 %	
	Linear		68 %	
0-1 sec	RBF	76 %	70 %	76 %
	Linear		72 %	

After grasp action started, it becomes rhythmic and automatic, so it may be difficult to classify in those stages.
→ FOCUS on 0-1 sec.

Use several frequency bands
and feature selection method

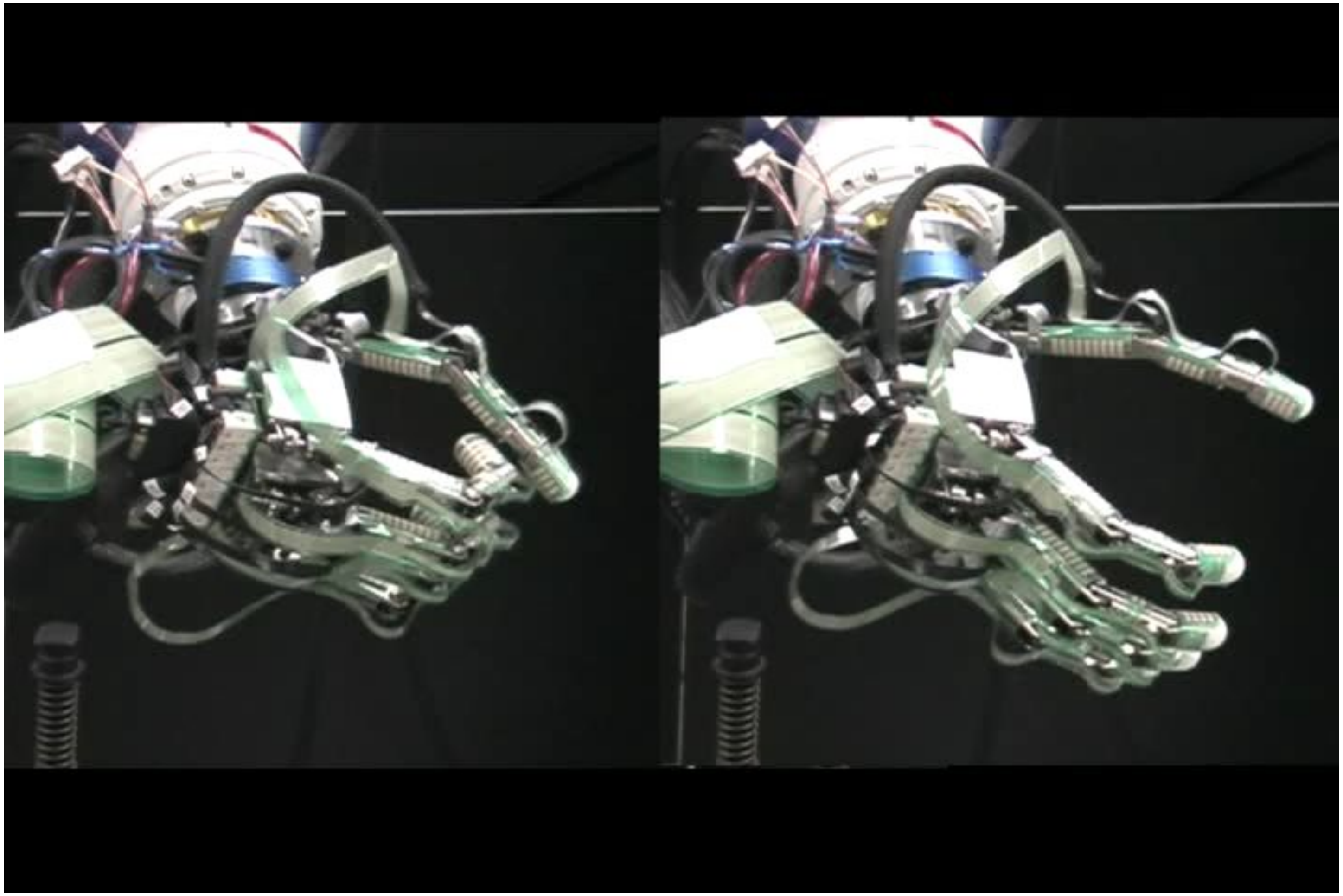
Step 2: Regress for each grasp type separately after classification



Power grasp sample trajectories

Precision grasp sample trajectories

Offline execution of power-grasp



Real aperture width

Reconstructed aperture width