

Methods of Cognitive Neuroscience

Focus on Language

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Studying the Damaged Brain

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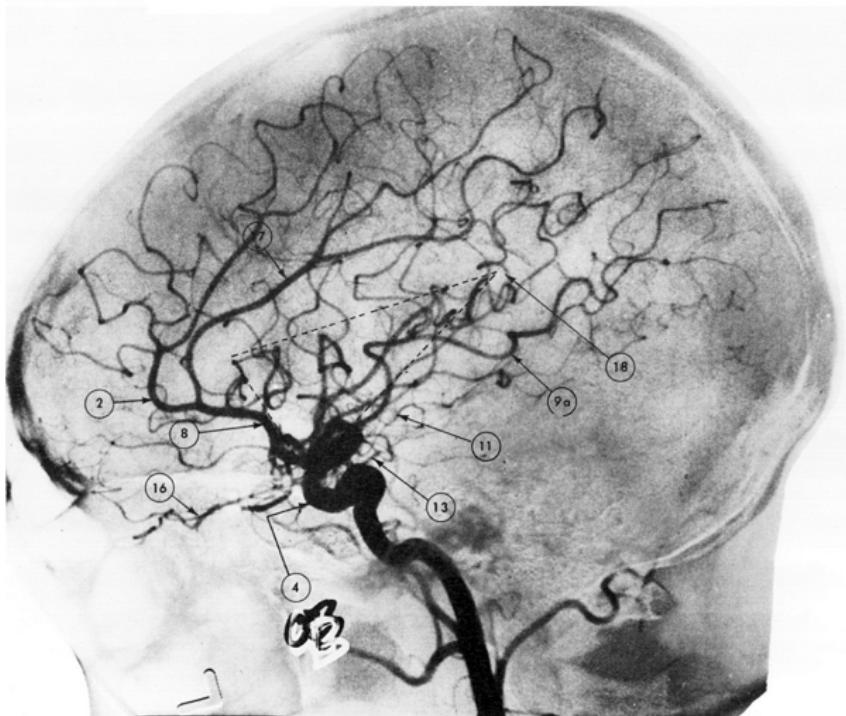
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- Epilepsy (癫痫病)

The brain's blood supply



Angiography (血管造影术) (DeArmond, Fusco, & Dewey, 1989)

Vascular Disorders

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- Ischemia (脑出血)

Tumors

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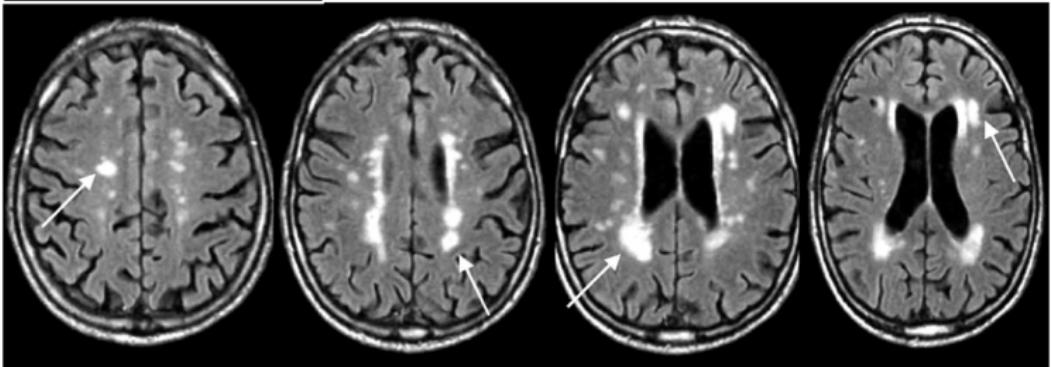
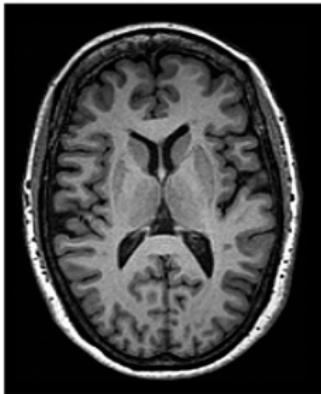
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- Glial cells and other supporting white matter tissues.
- Benign (良性的) vs Malignant or cancerous (恶性的)
- Brain tumor: location, prognosis

Degenerative and Infectious Disorders

Disorder	Type	Most common Pathology
Alzheimer's disease	Degenerative	Tangles (结节) and plaques (斑块) in limbic and tempoparietal cortex
Parkinson's disease	Degenerative	Loss of dopaminergic neurons (多巴胺神经元)
Huntington's disease	Degenerative	Atrophy (萎缩) of interneurons in caudate and putamen nuclei of basal ganglia
Pick's disease (皮克氏病)	Degenerative	Fronto-temporal atrophy (萎缩)
Progressive supranuclear palsy (PSP) (进行性核上性麻痹)	Degenerative	Atrophy of brainstem, including colliculus (丘)
Multiple sclerosis (多发性硬化)	Possibly infectious	Demyelination (髓鞘脱失), especially of fibers near ventricles
AIDS dementia (痴呆)	Viral infection	Diffuse white matter lesions
Herpes simplex (单纯性疱疹)	Viral infection	Destruction of neurons in temporal and limbic regions
Korsakoff's syndrome (健忘综合征)	Nutritional deficiency	Destruction of neurons in diencephalon and temporal lobes

A MRI image of Alzheimer's disease



Traumatic Brain Injury

- Traumatic Brain Injury (外伤性脑损伤) can result from either a closed or an open head injury

Epilepsy

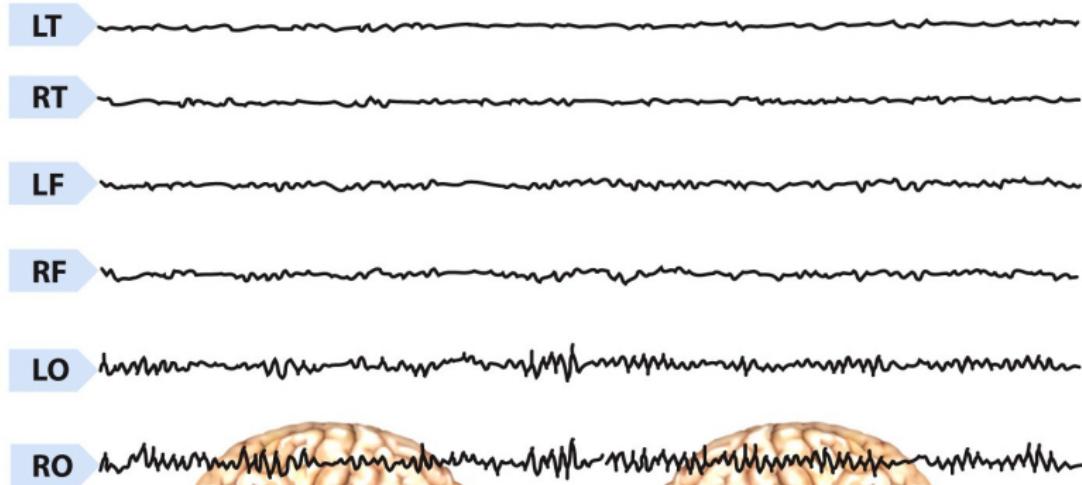
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Epilepsy

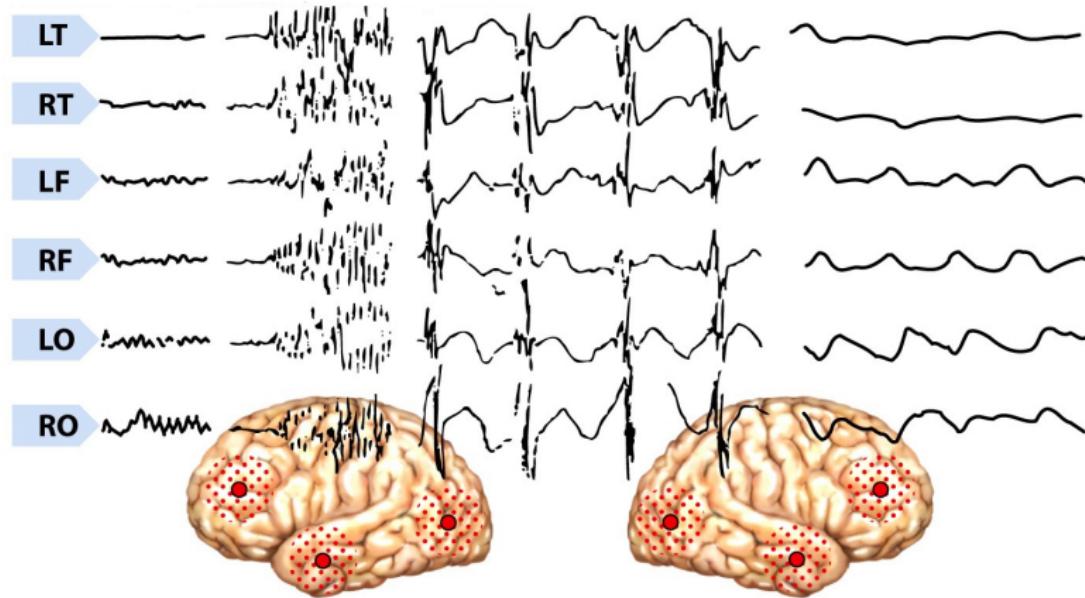
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- Although 0.5% of the general population has epilepsy, it is estimated that 5% of people will have a seizure at some point during life, usually triggered by an acute event such as trauma, exposure to toxic chemicals, or high fever.

Epilepsy and electroencephalography



(Chappell et al., 2006)

Epilepsy and electroencephalography



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Functional Neurosurgery

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Intervention to Alter or Restore Brain Function.

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- Epilepsy and Callosotomy (胼胝体离断术): Split-brain procedure;
- Parkinson's disease and Deep-brain stimulation (DBS) (深部脑刺激):
Electrodes are implanted in the basal ganglia.

Studying the Damaged Brain

Neurological dysfunction and Language deficits

Language deficits

Language deficits

- Aphasia (失语症): A broad term referring to the collective deficits in language comprehension and production that accompany neurological damage, even though the articulatory mechanisms are intact.

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- Speech apraxia (语言失用): Deficits in the motor planning of articulations.

Language deficits

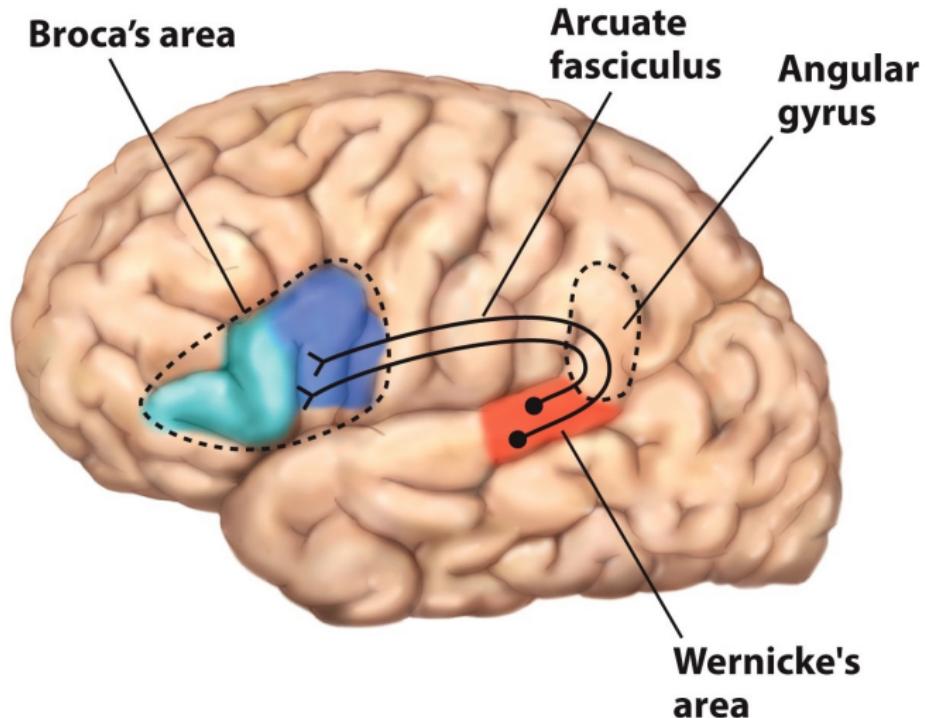
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 - ▶ Extremely common following brain damage
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- Speech apraxia (语言失用): Deficits in the motor planning of articulations.
- Dysarthria (构音障碍): Caused by the loss of control over articulatory muscles.

Lateral view of the brain of Leborgne

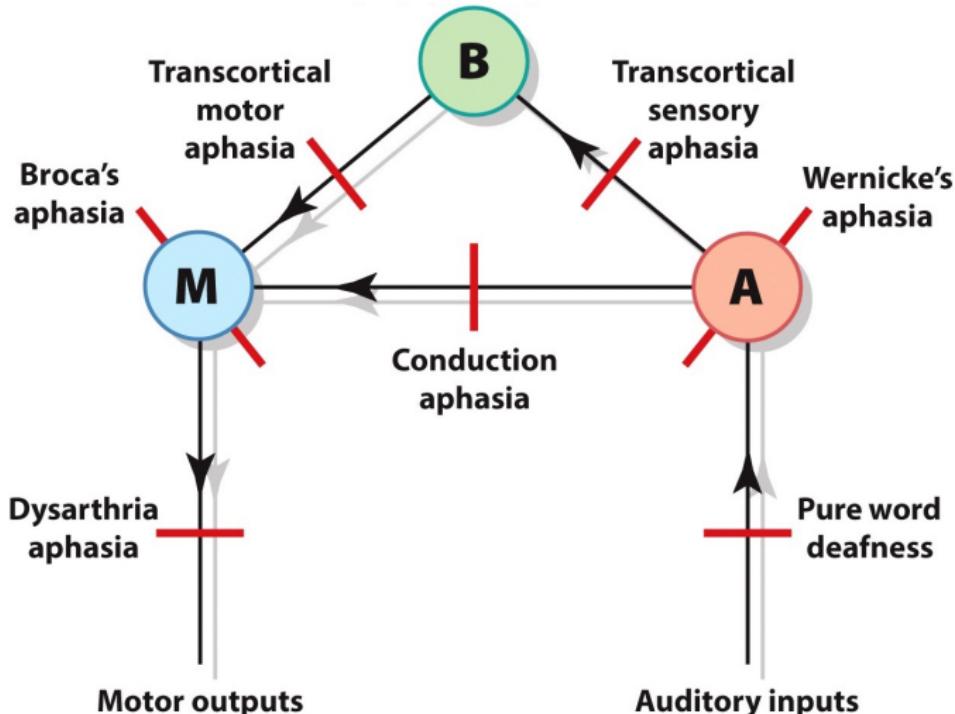


(Dronkers, Plaisant, Iba-Zizen, & Cabanis, 2007)

Broca's area and Wernicke's area

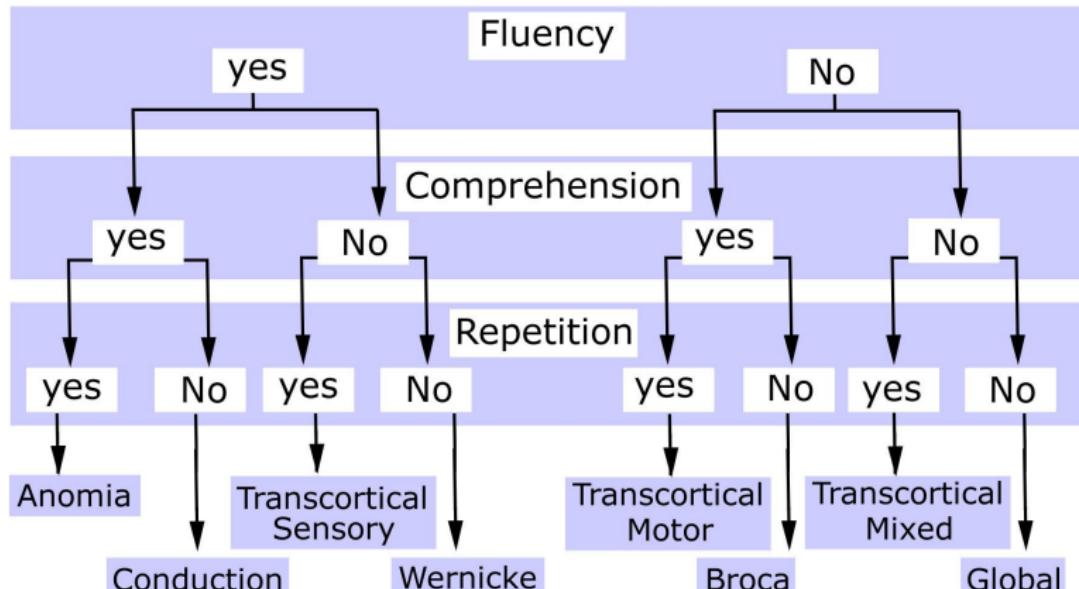


Lichtheim's model of language processing



Summary of Cortical Aphasias

Classification of the Aphasias

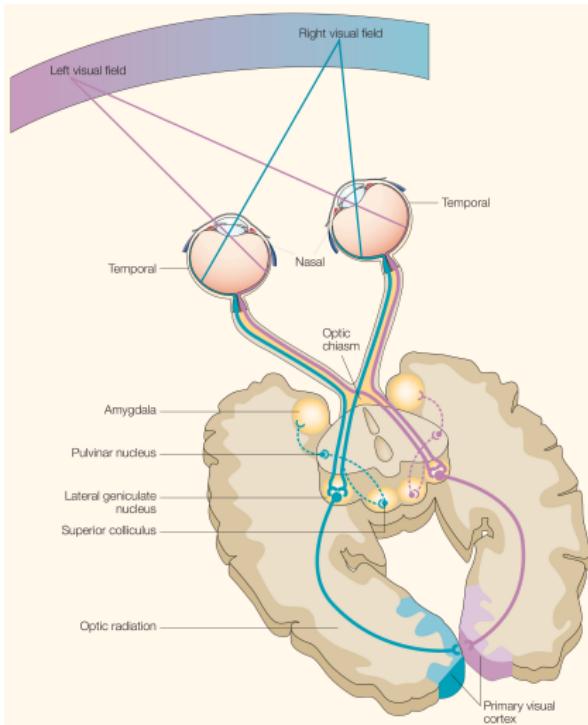


<https://emedicine.medscape.com/article/317758-overview>

Studying the Damaged Brain

Functional neurosurgery and language disorders

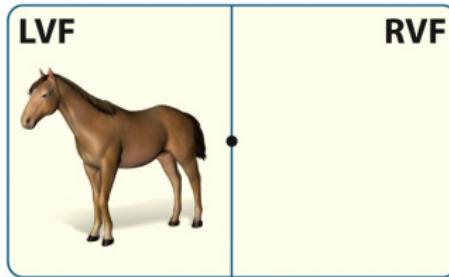
Information projecting into two hemispheres



(Hannula, Simons, & Cohen, 2005)

Object naming

Visual stimulus



Examiner: "What was it?" "What goes on it?"

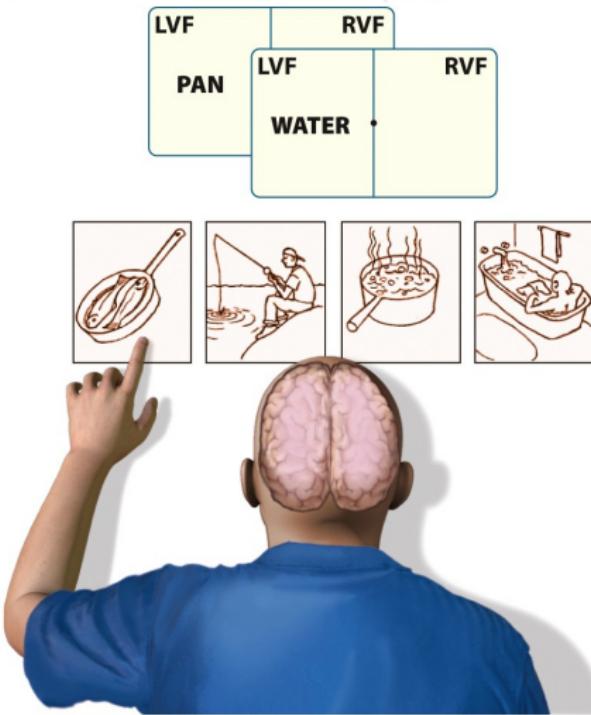
Verbal response: "I don't know." "I don't know."

**Left-hand drawing:
(saddle)**



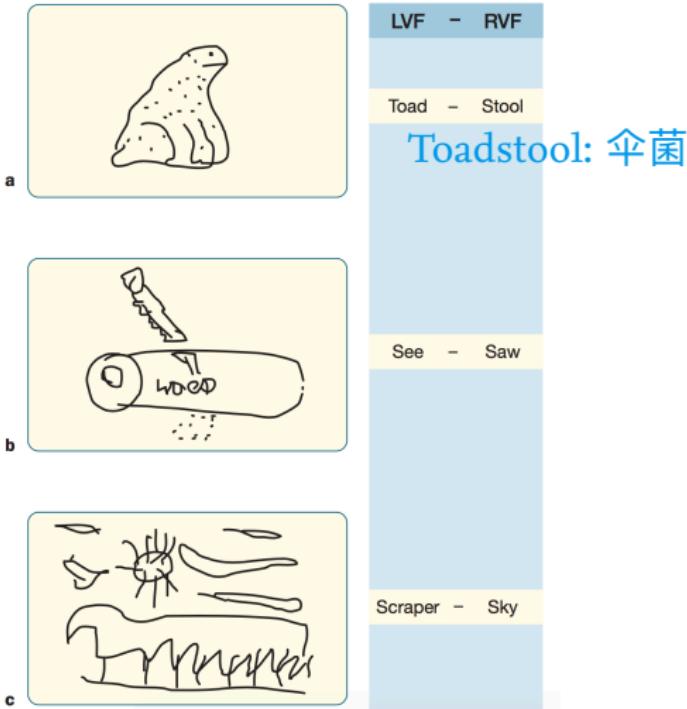
(Gazzaniga et al., 2014, p.138)

Make inference



(Gazzaniga et al., 2014, p.138)

Information integration

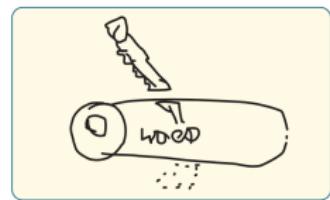


(Gazzaniga et al., 2014, p.142)

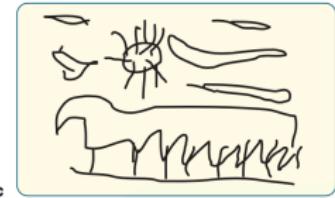
Information integration



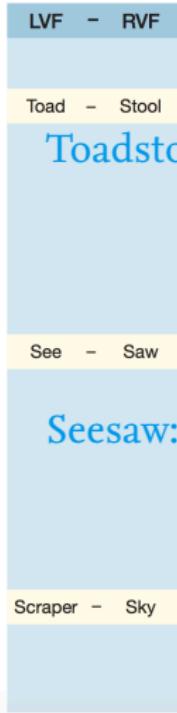
a



b



c

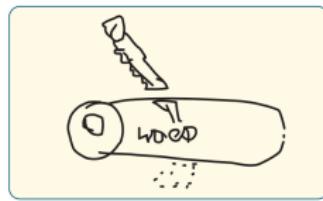


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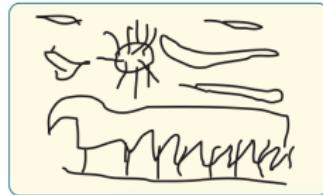
Information integration



a



b



c

LVF - RVF

Toad - Stool

Toadstool: 伞菌

See - Saw

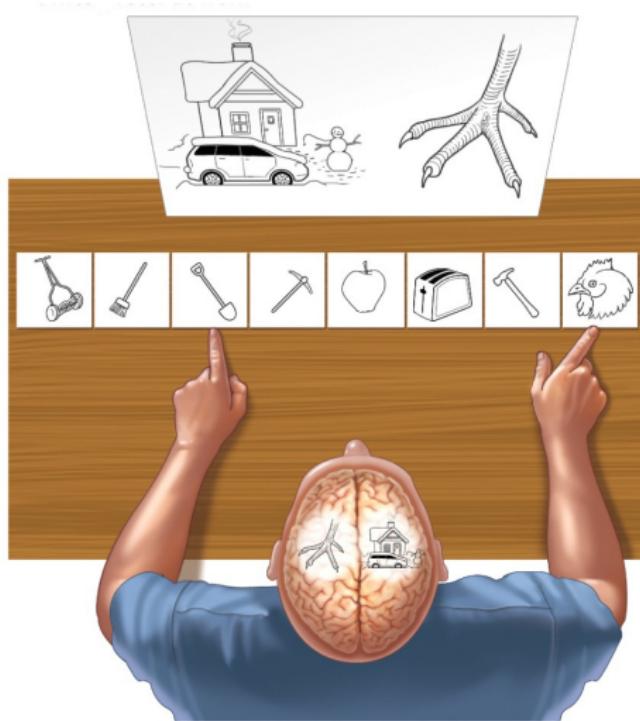
Seesaw: 跷跷板

Scraper - Sky

Skyscraper: 摩天大楼

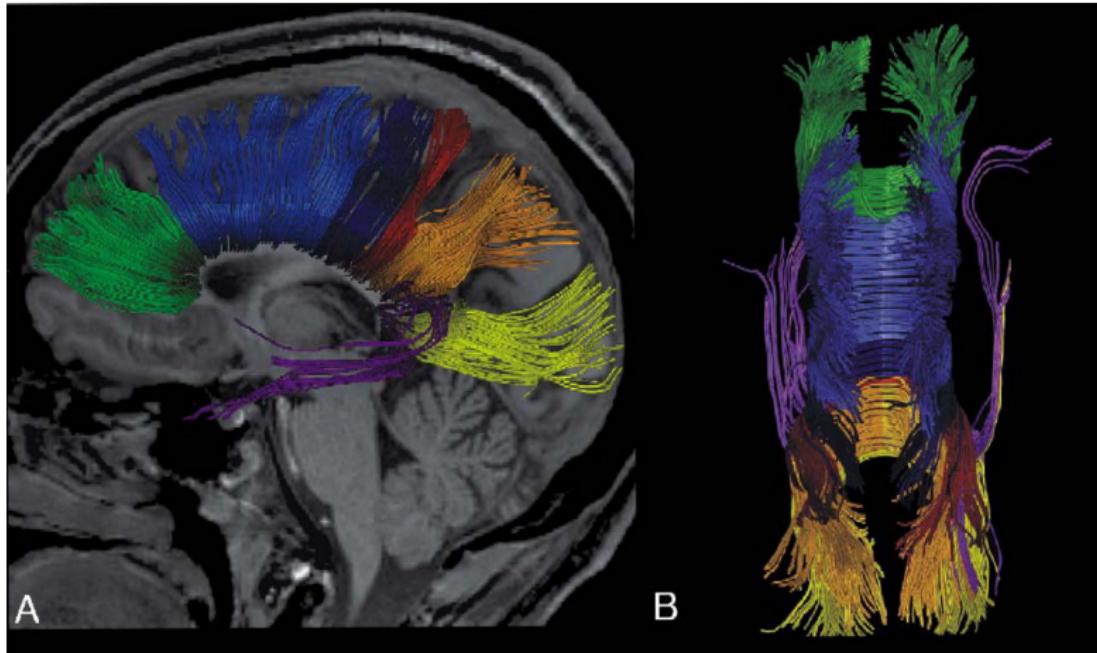
(Gazzaniga et al., 2014, p.142)

The interpreter



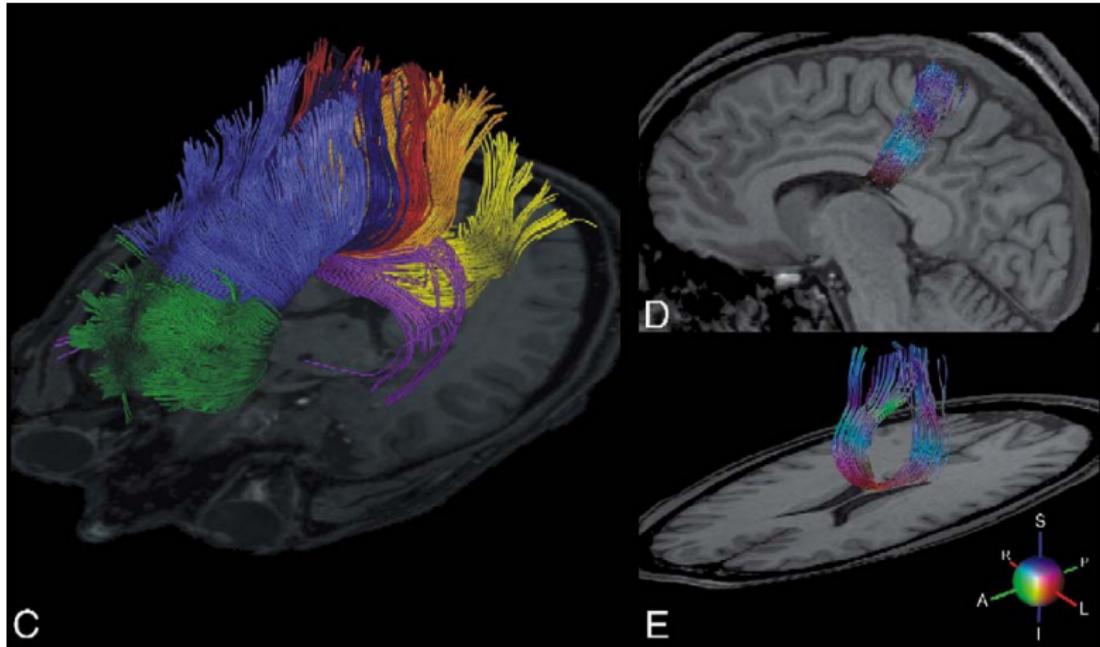
(Gazzaniga et al., 2014, p.147)

Callosal projection



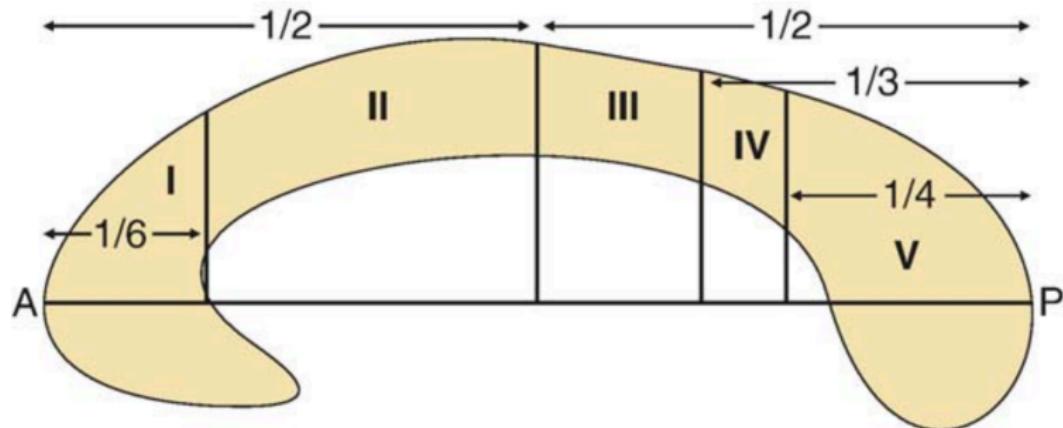
(Hofer & Frahm, 2006)

Callosal projection



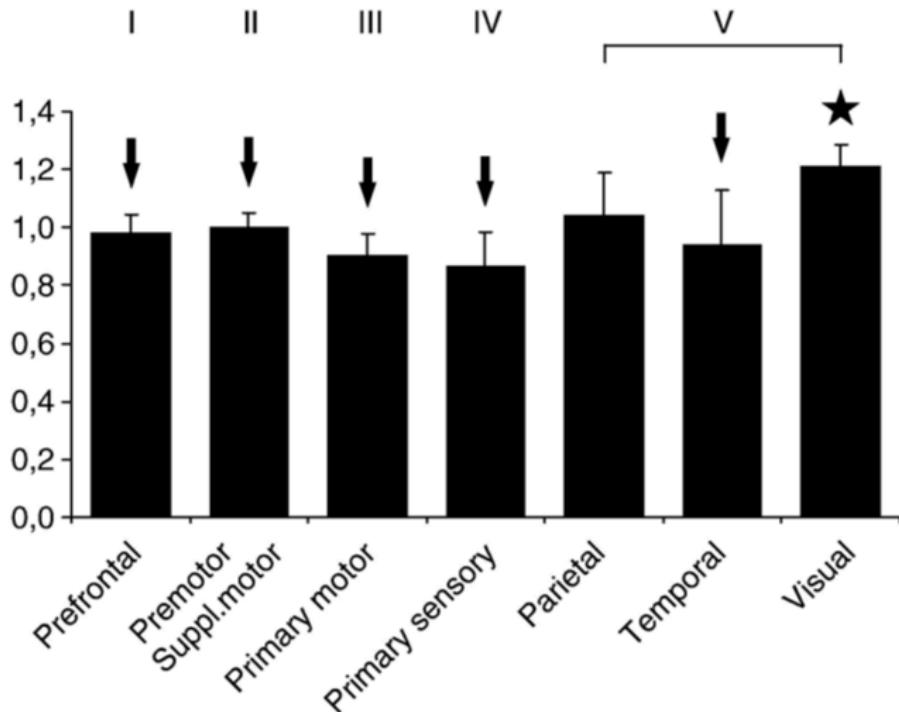
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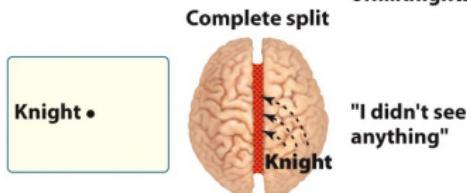
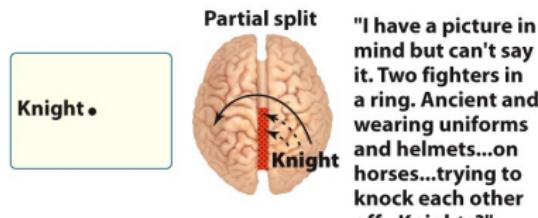
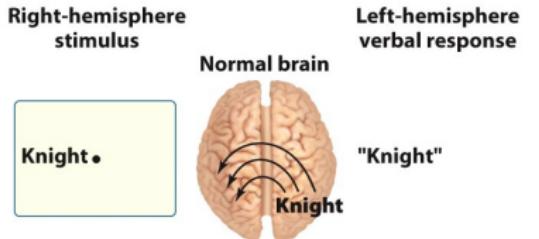
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Callosal Function Specificity



(Gazzaniga et al., 2014, p.136)

Perturbing Neural Function

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- Pharmacology (药理学)

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(tDCS, 经颅直流电刺激)

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- Genetic manipulation (基因控制)

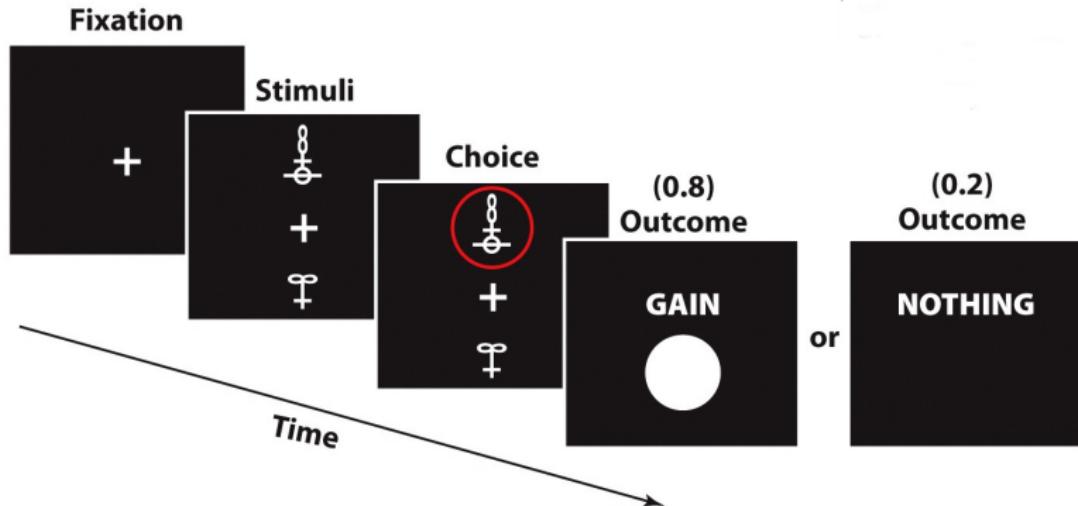
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 - ▶ Knockout gene (基因敲除)

Perturb Neural Function

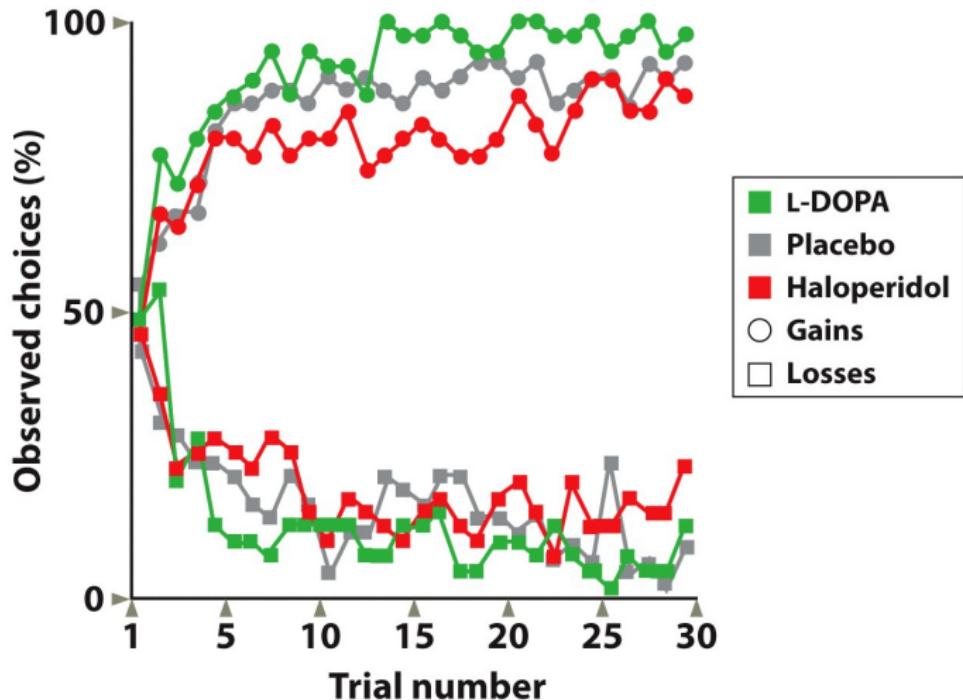
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 - ▶ Optogenetics (光遗传学)

Pharmacology



(Pessiglione, Seymour, Flandin, Dolan, & Frith, 2006)

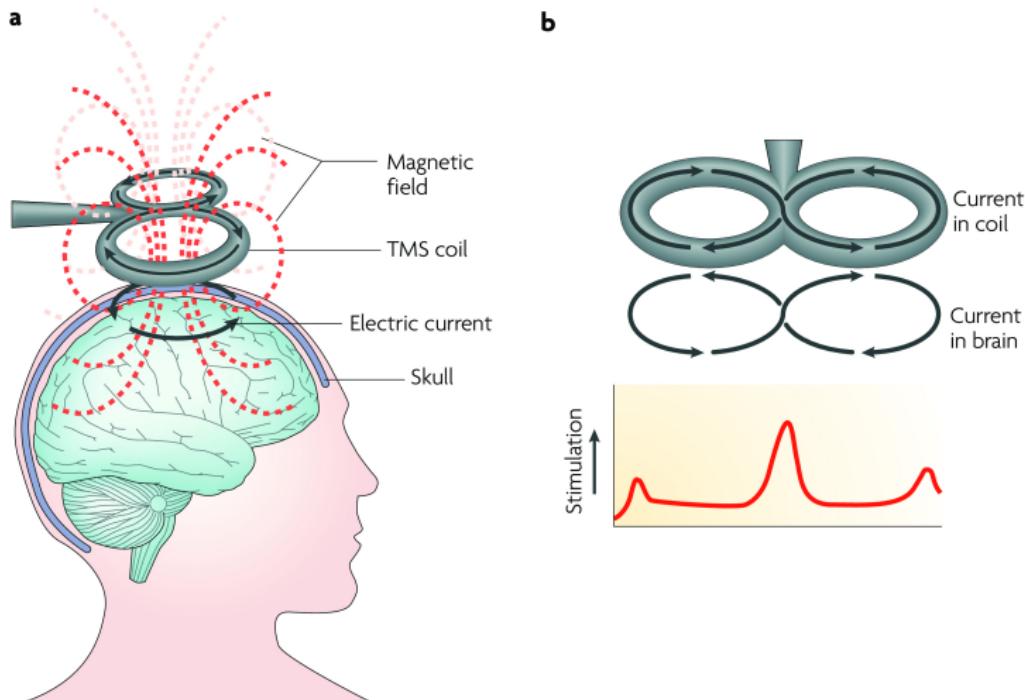
Pharmacology



Transcranial Magnetic Stimulation

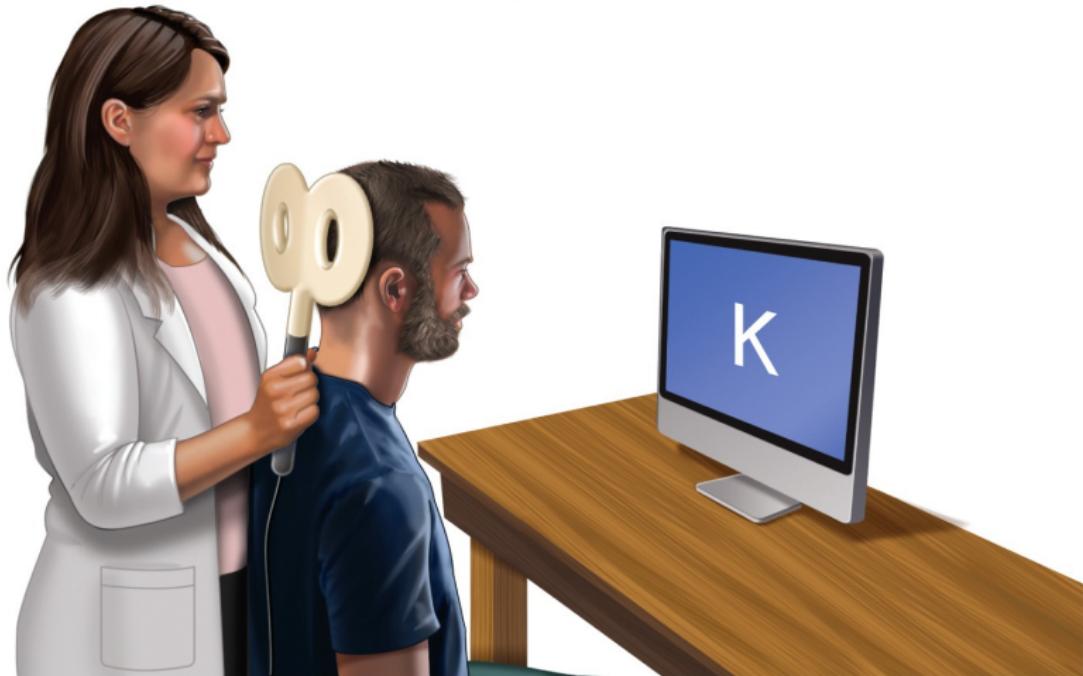


Transcranial Magnetic Stimulation

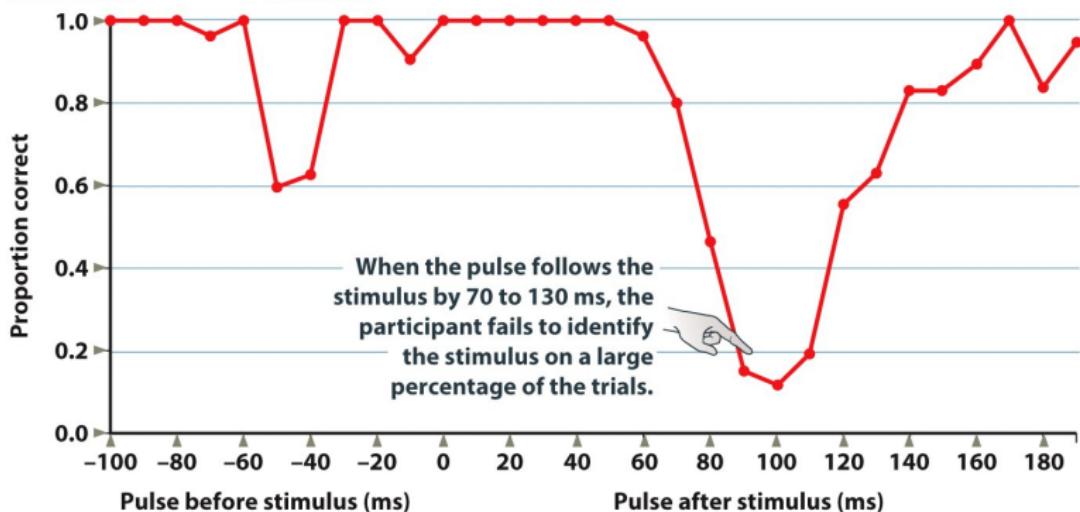


Occipital lobe and letter identification

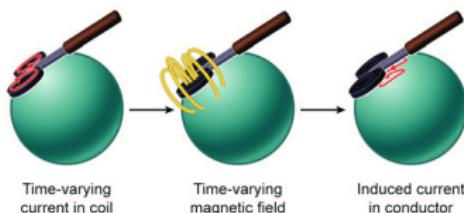
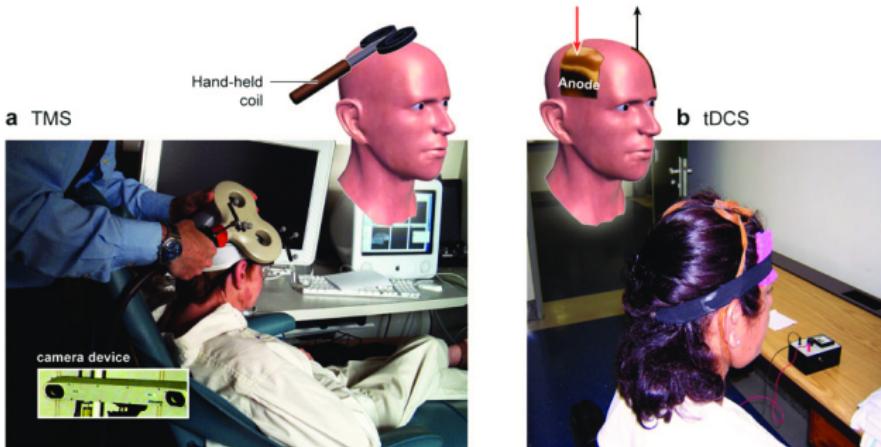
Transcranial magnetic stimulation over the occipital lobe



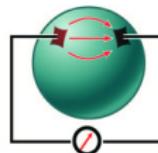
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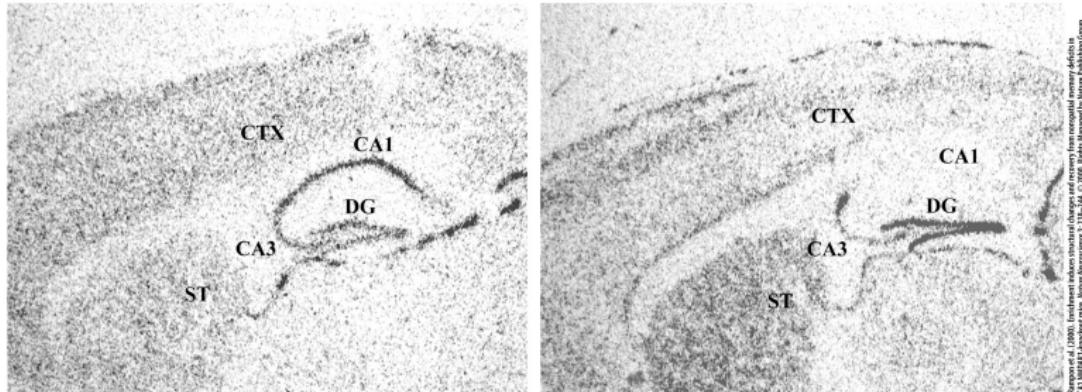
Transcranial Direct Current Stimulation



DC current applied via pair of electrodes; current induced in conductor

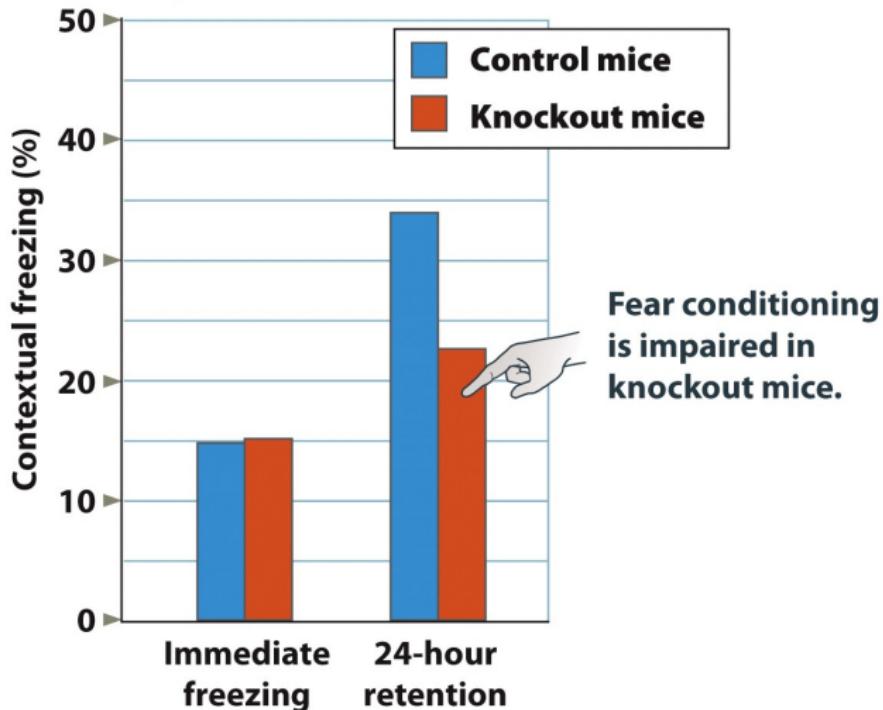


Gene knockout



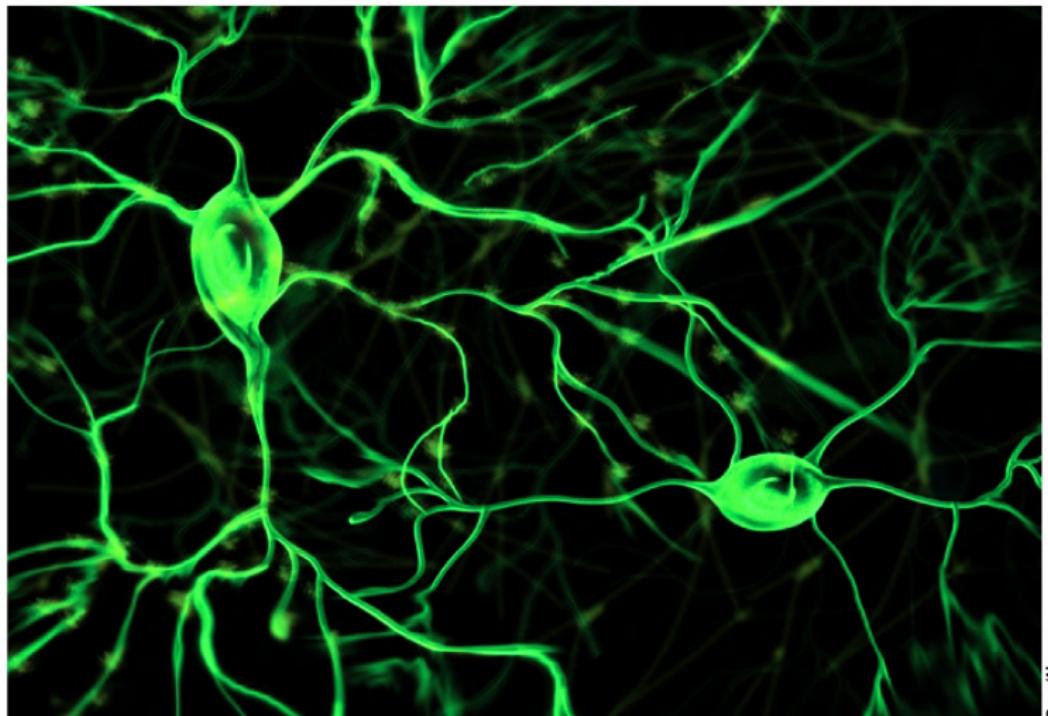
(Rampton et al., 2000)

Gene knockout

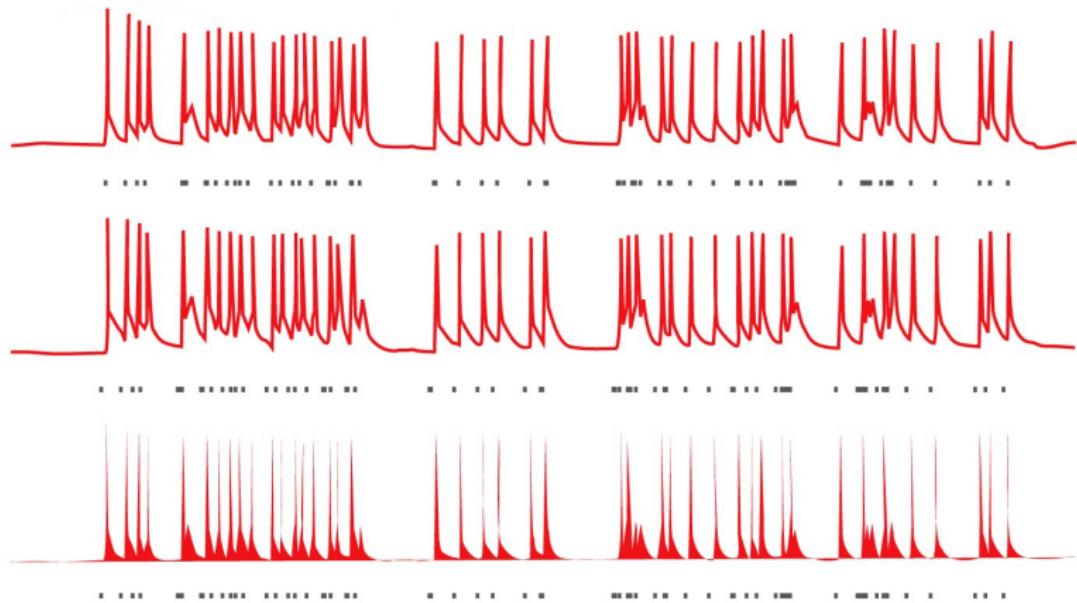


Fear conditioning
is impaired in
knockout mice.

Optogenetics



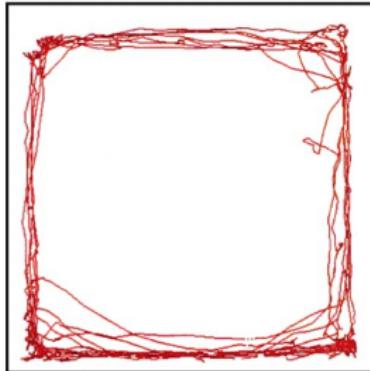
Optogenetics



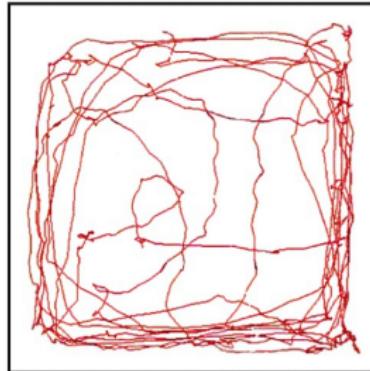
(Tye et al., 2011)

Optogenetics

Off



On



Studying Neural function

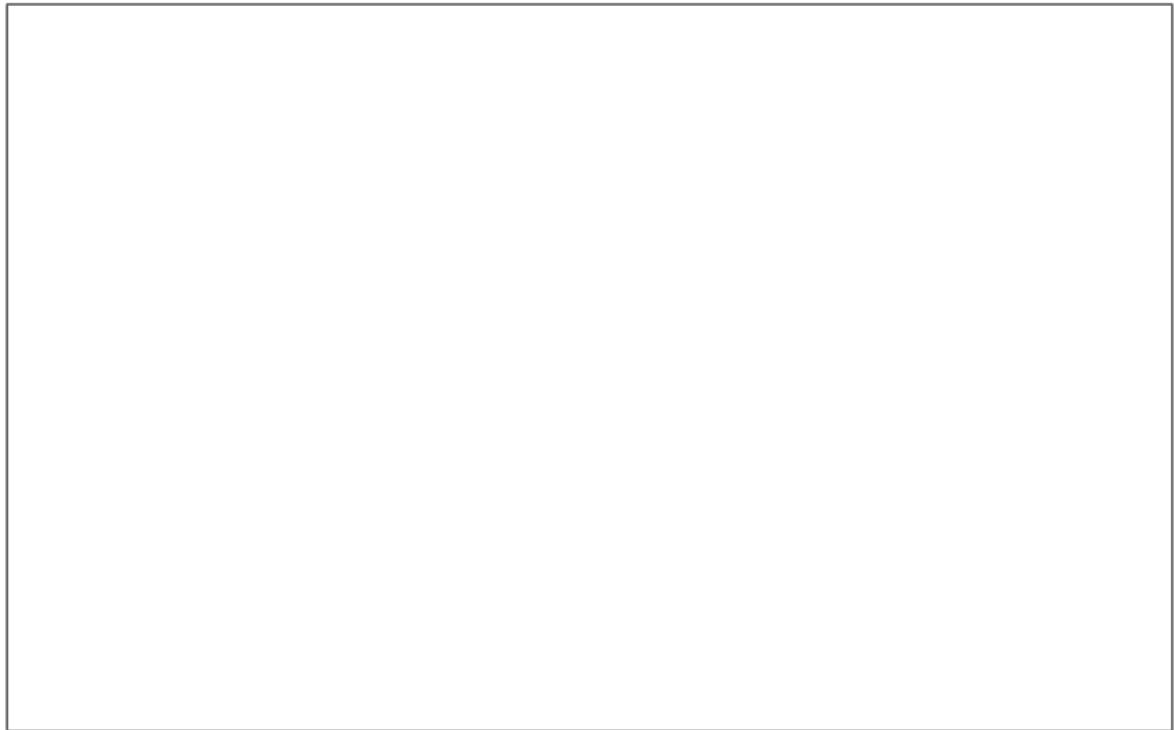
Studying Neural function

- Single-Cell Recording
- Magnetoencephalography (MEG, 脑磁图仪)
- Scalp Electroencephalography (EEG, 脑电仪)
- Intracranial electroencephalography (iEEG) or
Electrocortogram (ECoG, 皮层下脑电)

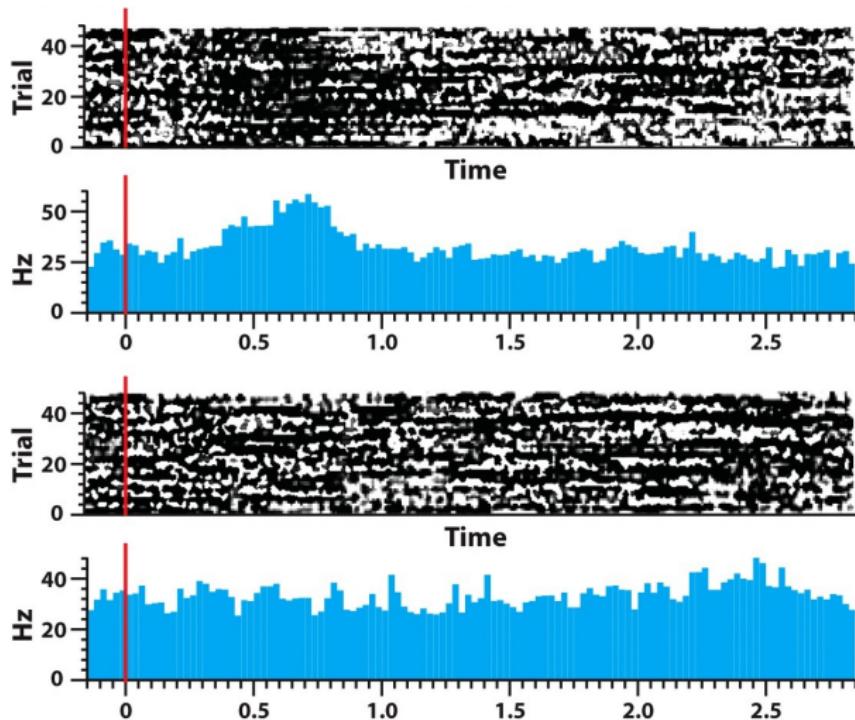
Studying Neural function

Single-Cell Recording

Neural signals

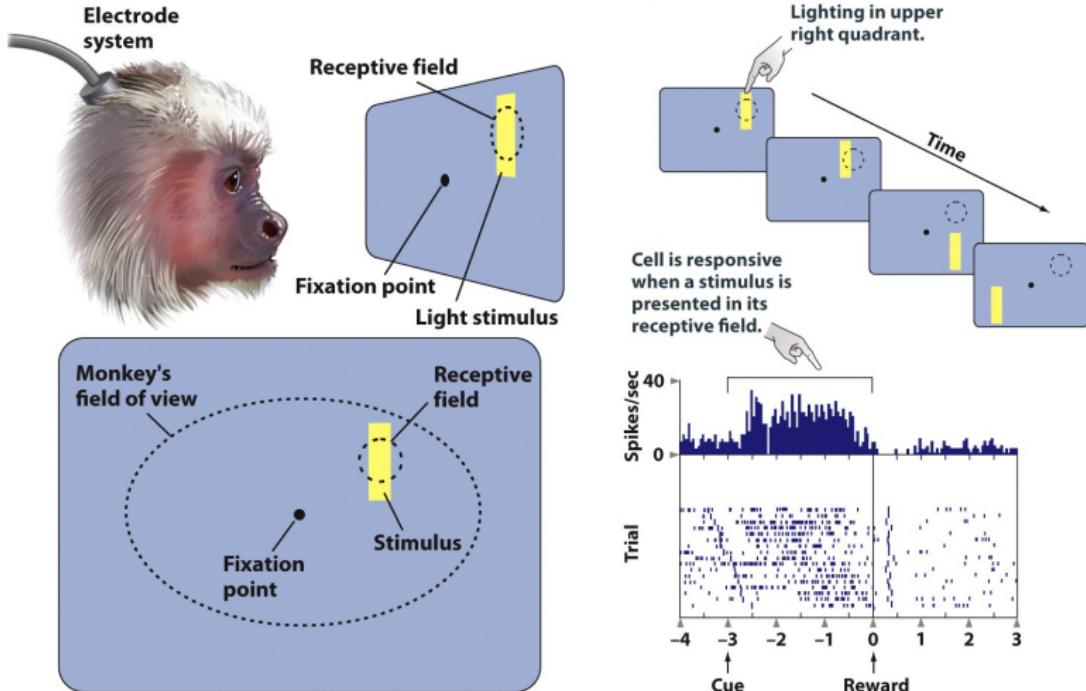


Raster plots (光栅图)



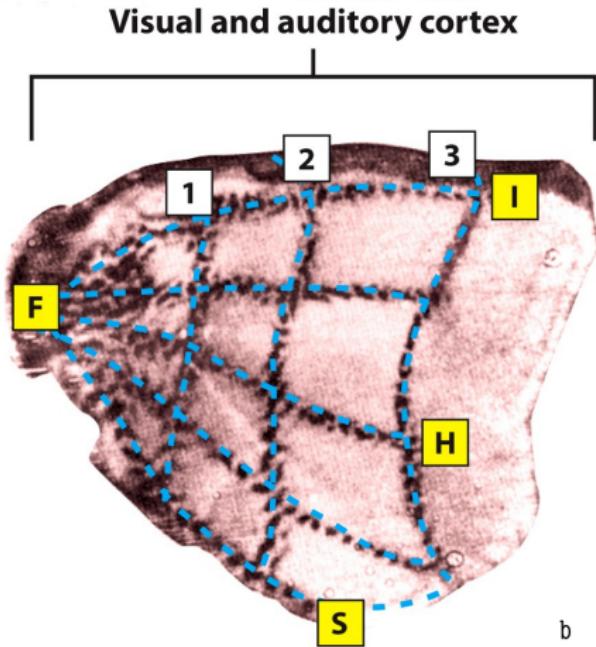
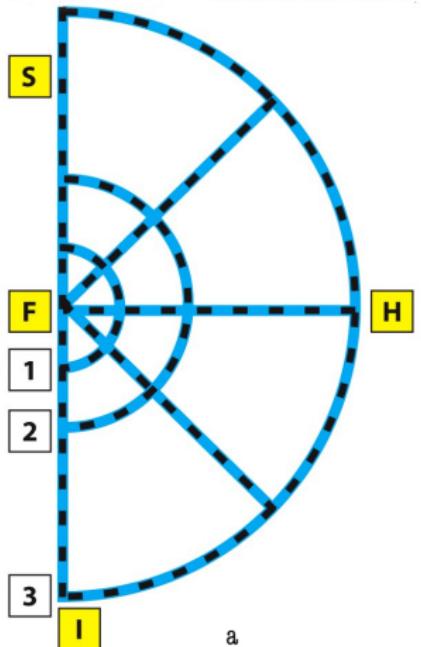
(Gonzalez Andino & Grave de Peralta Menendez, 2012)

Single-Cell Recordings in Animals



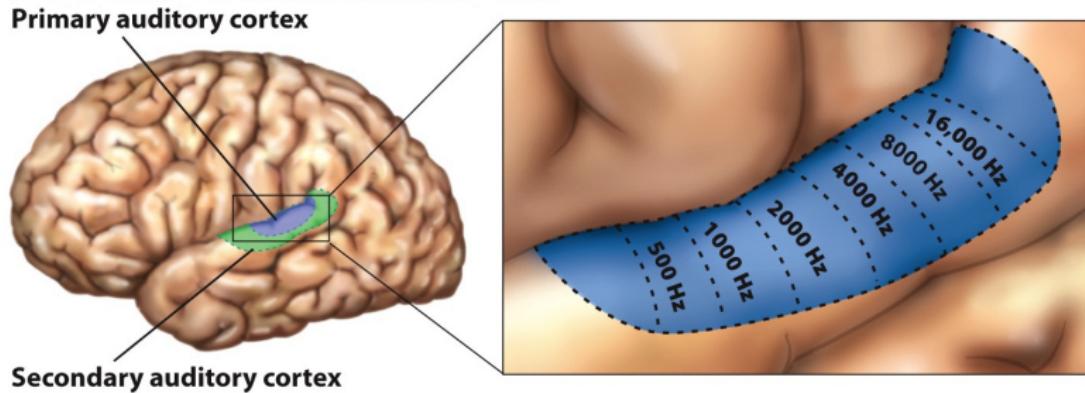
(Mori & Zhang, 2006)

Retinotopic map



(Gazzaniga et al., 2014, p.98)

Tonotopic or Cochleotopic maps

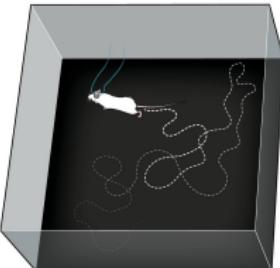
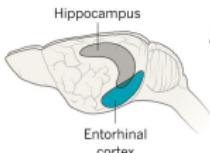


(Gazzaniga et al., 2014, p.98)

Place cells

A SENSE OF PLACE

Edvard and May-Britt Moser study grid cells in the brain's entorhinal cortex that help animals to understand where they are.



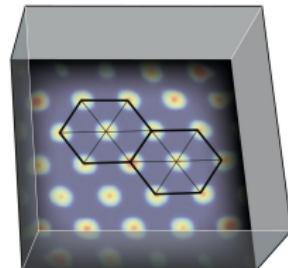
RAT ON THE RUN

The Mosers insert electrodes into a rat's entorhinal cortex and measure electrical signals from individual grid cells as the rat runs around a box, eating chocolate treats.



FIRING PATTERN

A single grid cell fires when a rat crosses certain points on the floor; it turns out that these points form a hexagonal grid, like a honeycomb.



POSITIONING SYSTEM

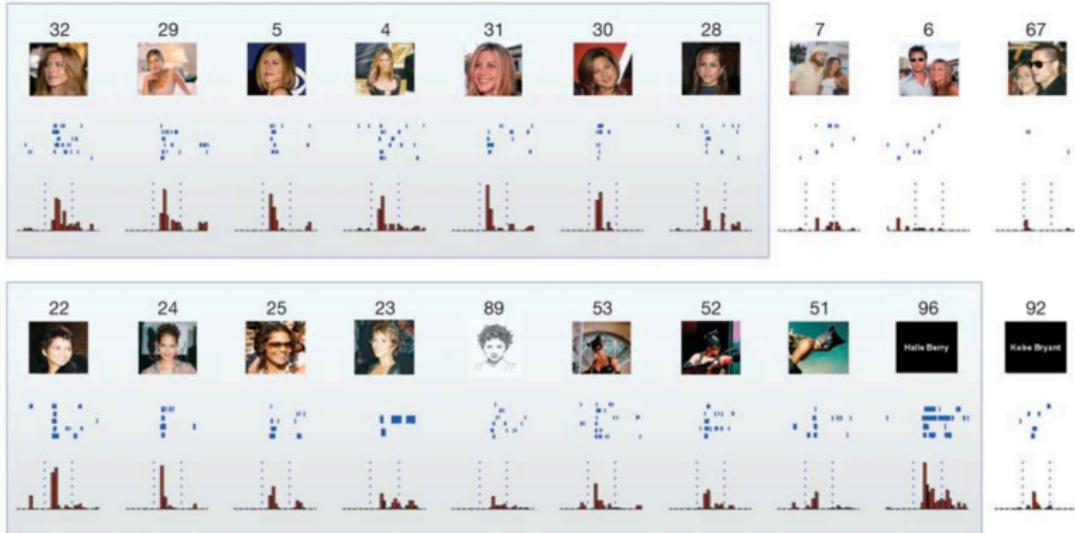
A hexagonal pattern gives the highest-possible spatial resolution with the fewest cells. Each cell generates its own grid, and these overlapped patterns help the animal to recognize its location and direction.

(Abbott, 2014)

The Nobel Prize in Physiology or Medicine 2014 was divided, one half awarded to John O'Keefe, the other half jointly to May-Britt Moser and Edvard I. Moser

“for their discoveries of cells that constitute a positioning system in the brain”.

Single-Cell Recordings in human



(Quiroga, Reddy, Kreiman, Koch, & Fried, 2005)

Studying Neural function

MEEG

EEG and MEG

EEG and MEG

- 脑电仪是记录大脑中生物电信号的脑成像技术。

Electro Encephalo Graphy (EEG)
电 脑 图

EEG and MEG

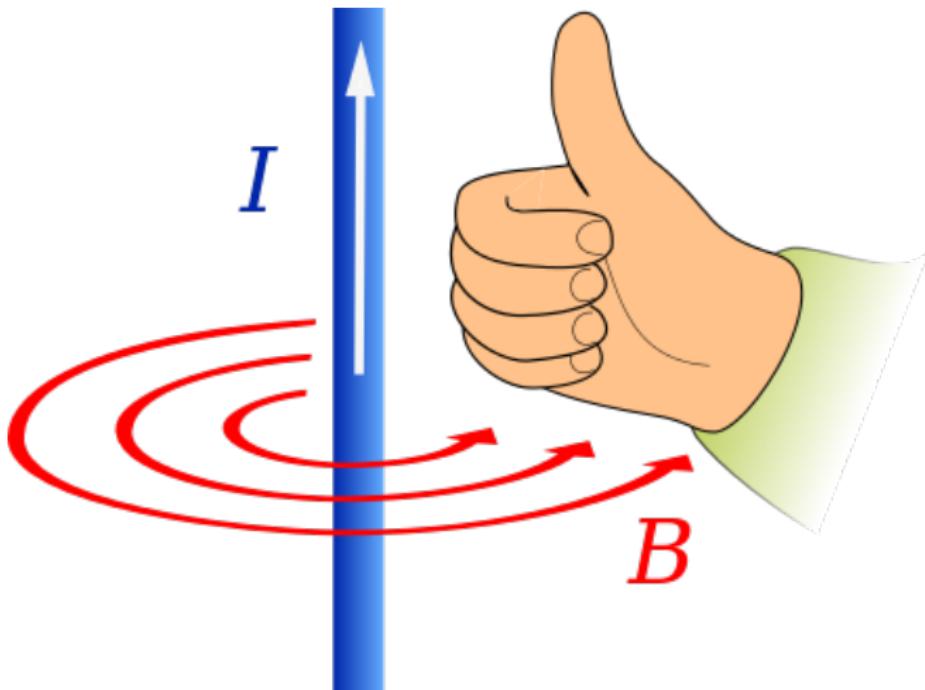
- 脑电仪是记录大脑中生物电信号的脑成像技术。
Electro Encephalo Graphy (EEG)
电 脑 图
- 脑磁图仪是记录大脑中生物磁信号的脑成像技术。
Magneto Encephalo Graphy (MEG)
磁 脑 图

Electroencephalography

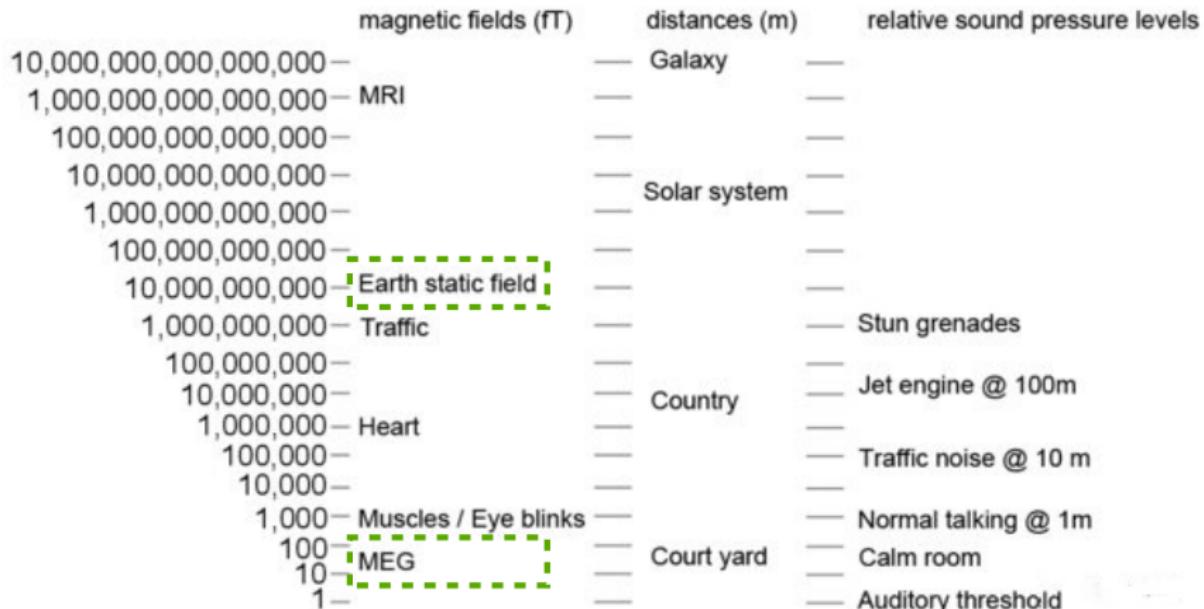


(Gazzaniga et al., 2014, p.99)

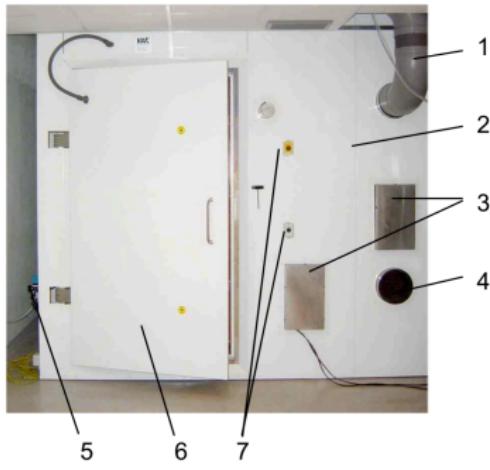
Bioelectric and biomagnetic signals



Biomagnetic signals are tiny



Magnetically shielded room



SQUIDs

Superconducting Quantum Interference Device (**SQUID**s)

SQUIDs

Superconducting Quantum Interference Device (SQUIDs)

超导

量子

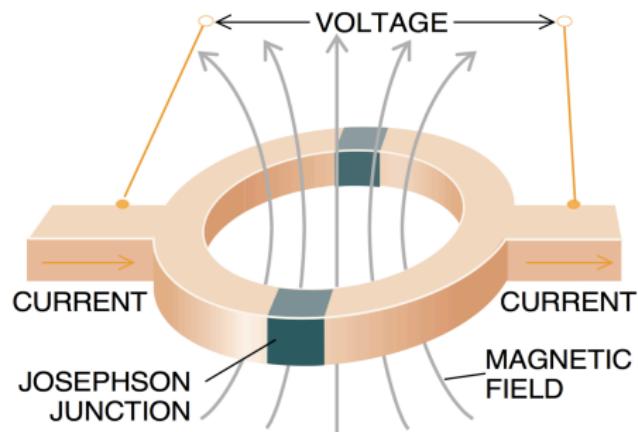
干涉

仪

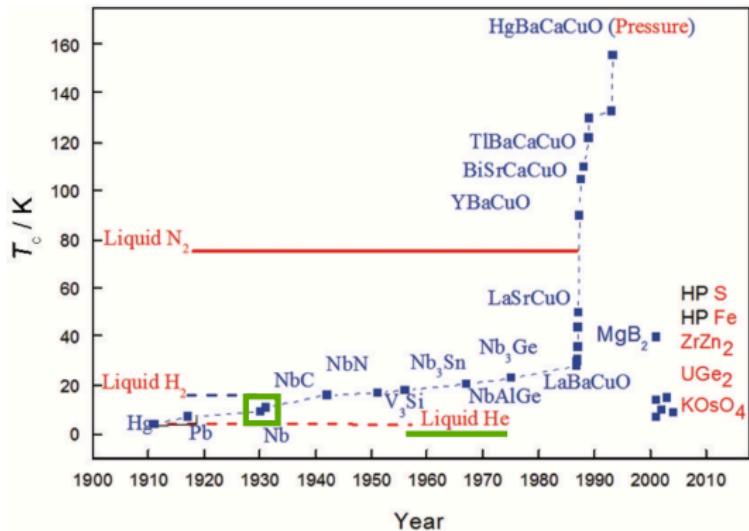
SQUIDS

Superconducting Quantum Interference Device (SQUIDS)

超导 量子 干涉 仪



Superconductors

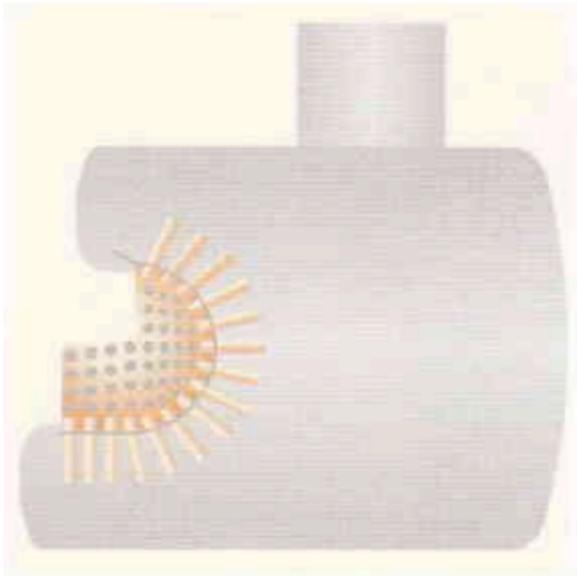


- 钨临界温度 (Nobium, Nb): -263 摄氏度
- 液氦沸点 (Liquid Helium, LHe): -269 摄氏度

Dewar and Boat in a bottle

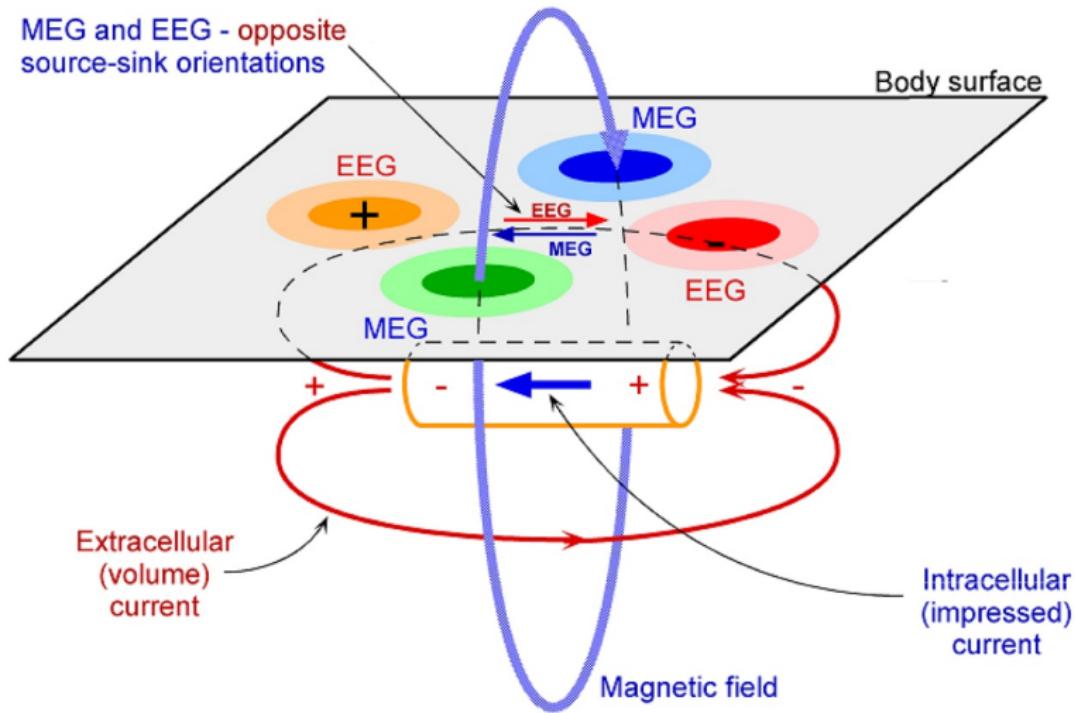


全脑磁束计



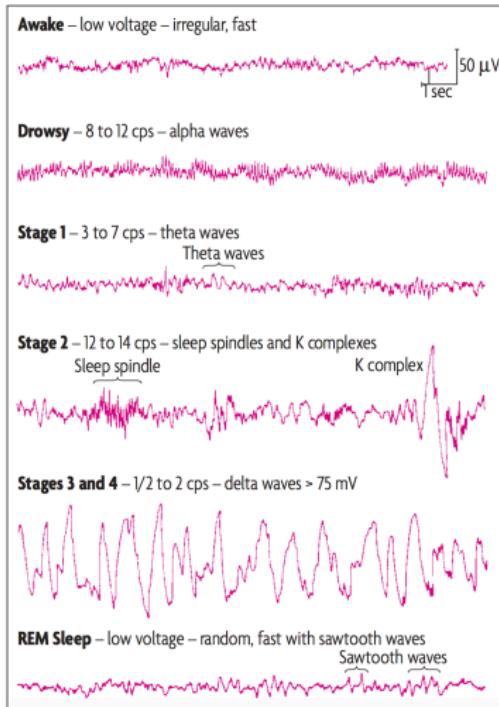
杜瓦罐形状

Comparing EEG and MEG

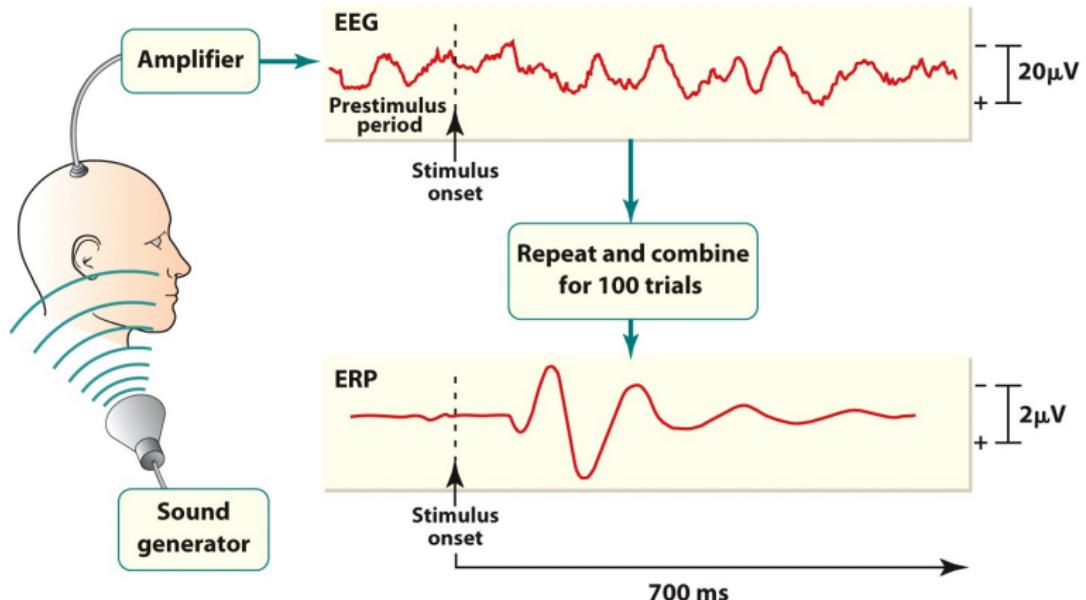


(Vrba & Robinson, 2001)

EEG profiles at different states of consciousness

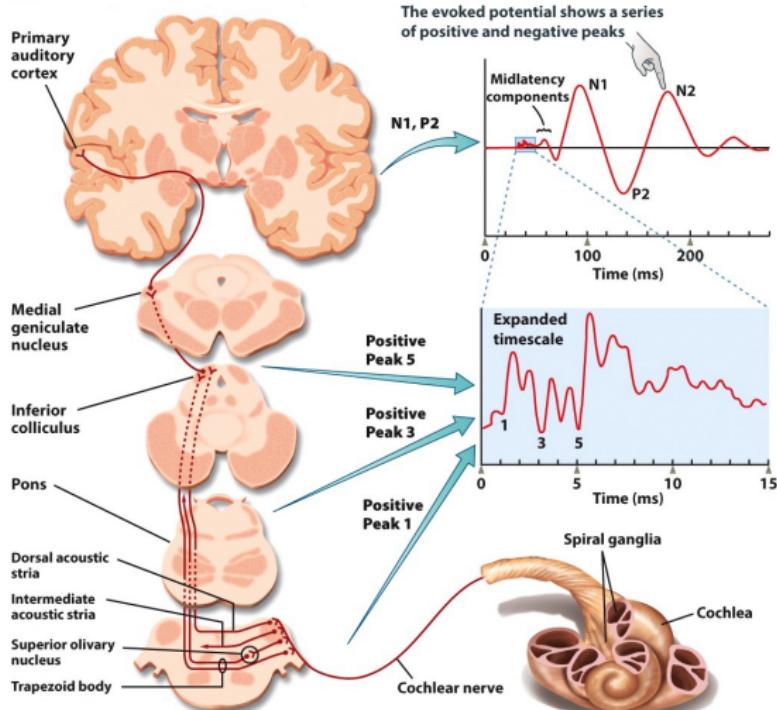


Event-related potentials



(Gazzaniga et al., 2014, p.100)

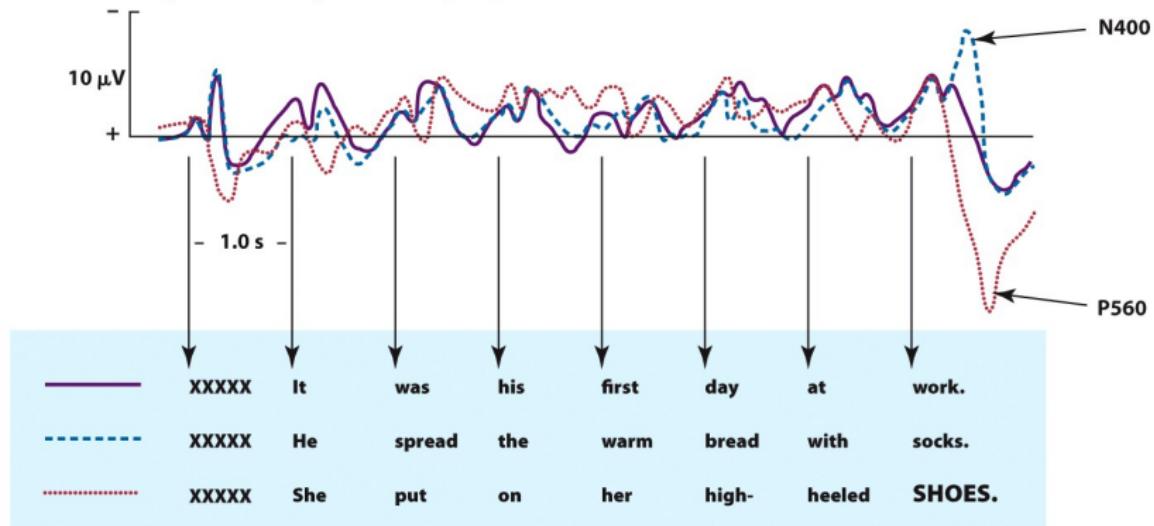
Auditory evoked potentials (AERs)



(Quiroga et al., 2005)

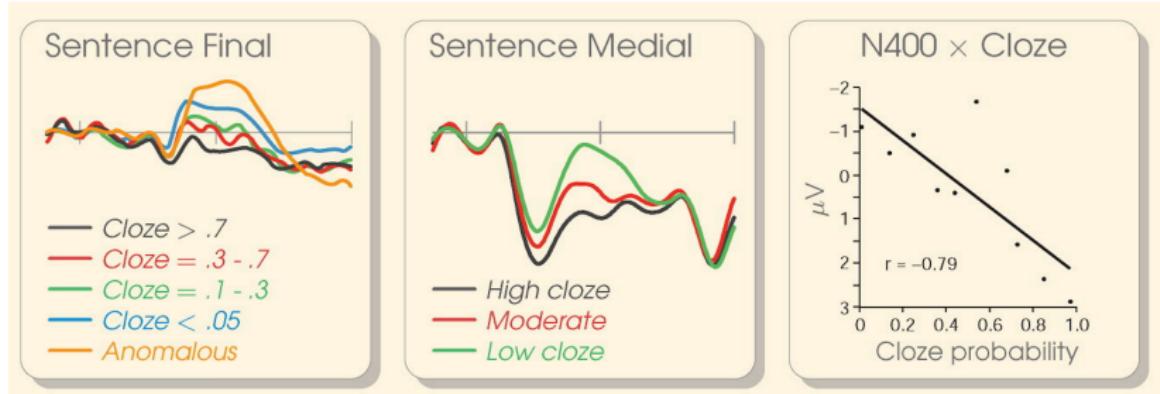
Semantic Processing and the N400 Wave

ERPs reflecting semantic aspects of language



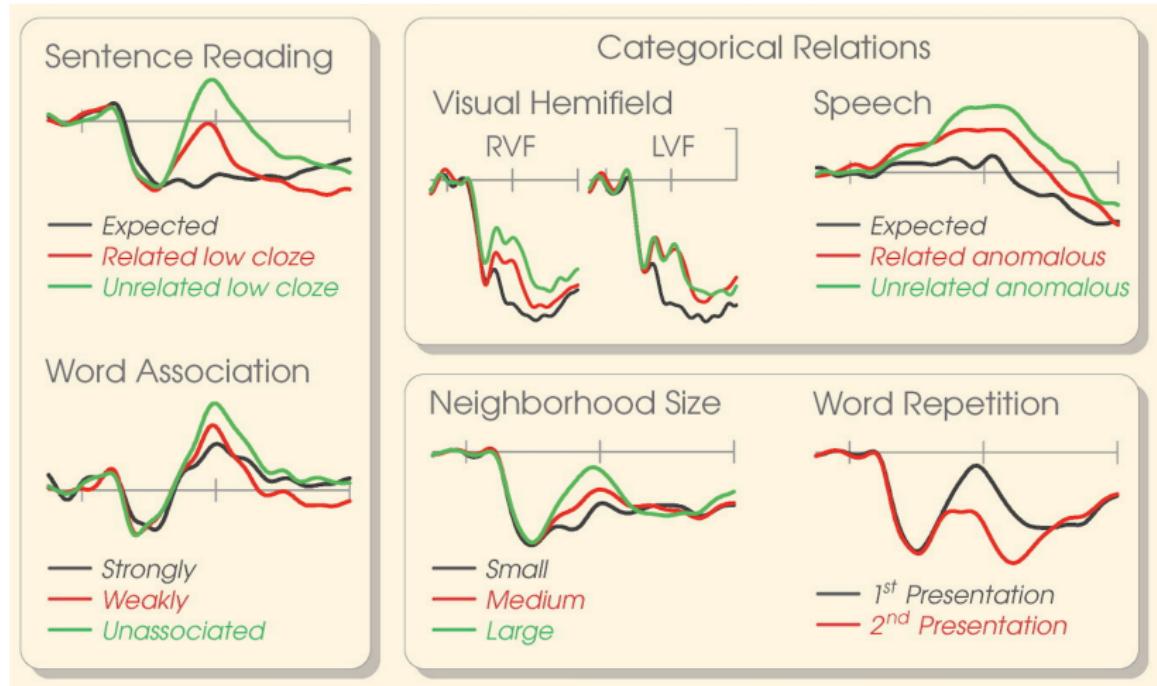
(Kutas & Hillyard, 1980)

Semantic Processing and the N400 Wave



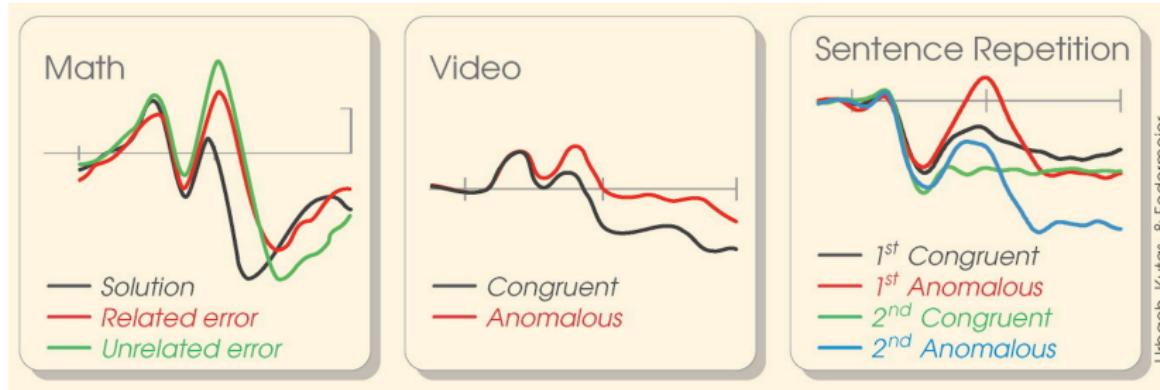
(Kutas & Federmeier, 2011)

Semantic Processing and the N400 Wave



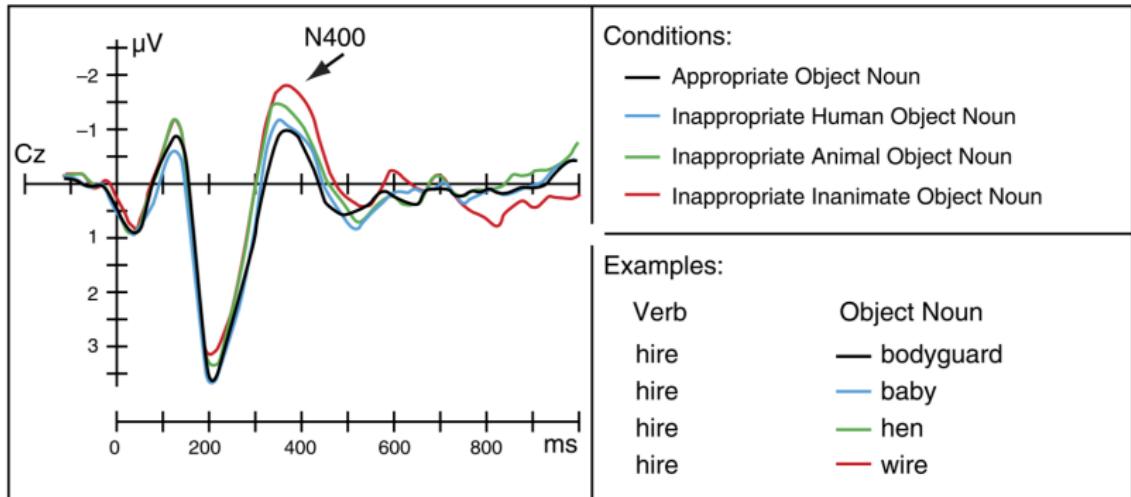
(Kutas & Federmeier, 2011)

Semantic Processing and the N400 Wave



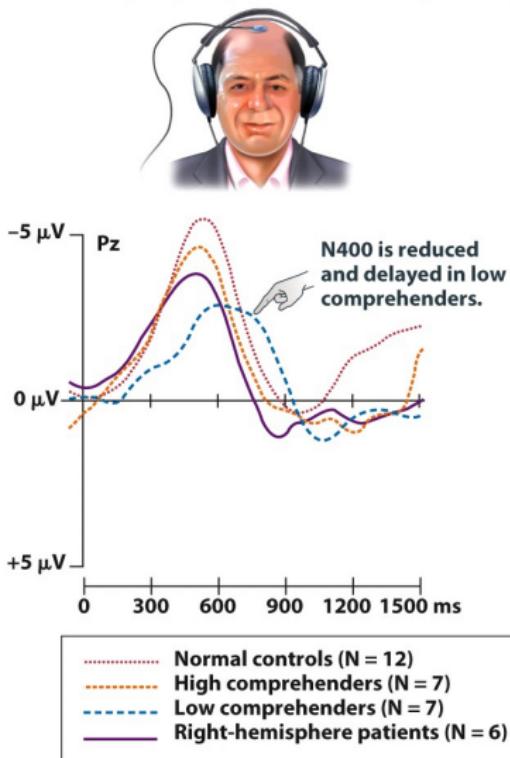
(Kutas & Federmeier, 2011)

Semantic Processing and the N400 Wave



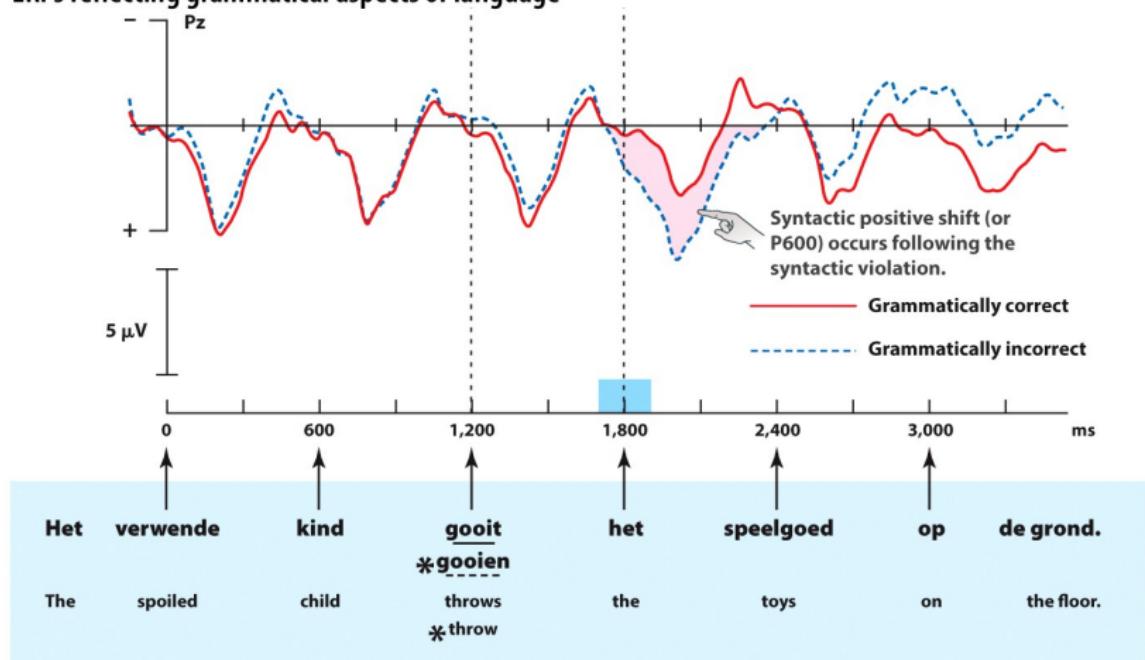
(Friederici, 2011)

Semantic Processing and the N400 Wave



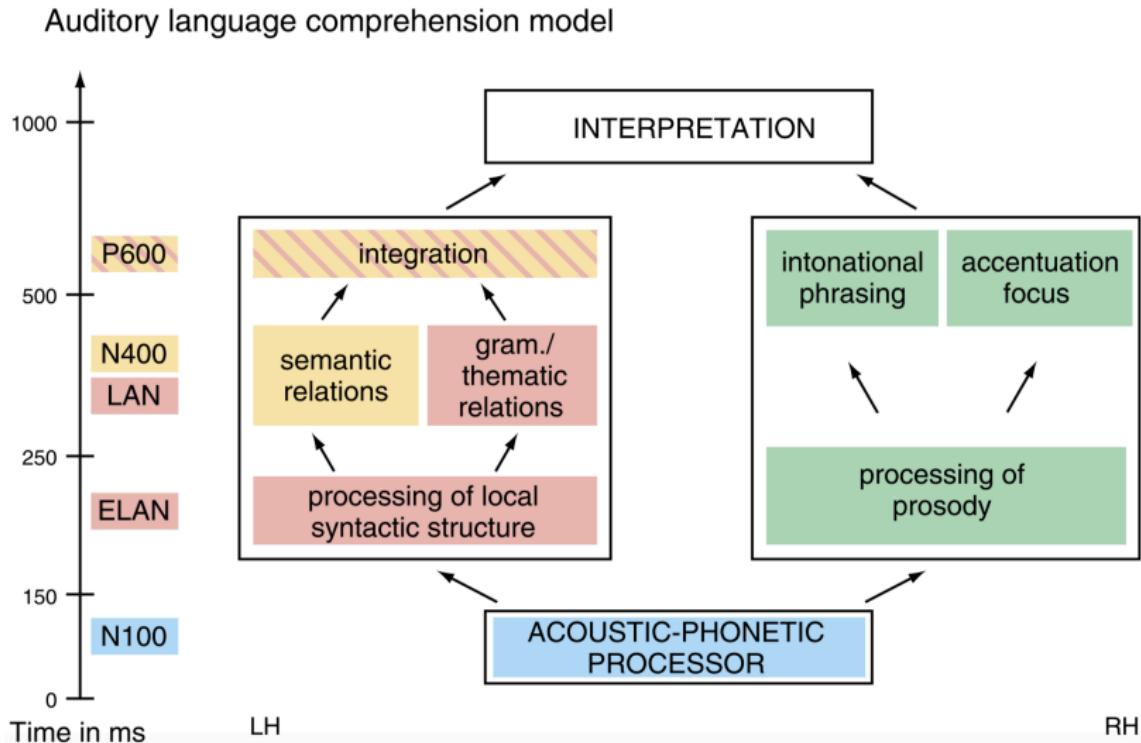
Syntactic Processing and the P600 Wave

ERPs reflecting grammatical aspects of language

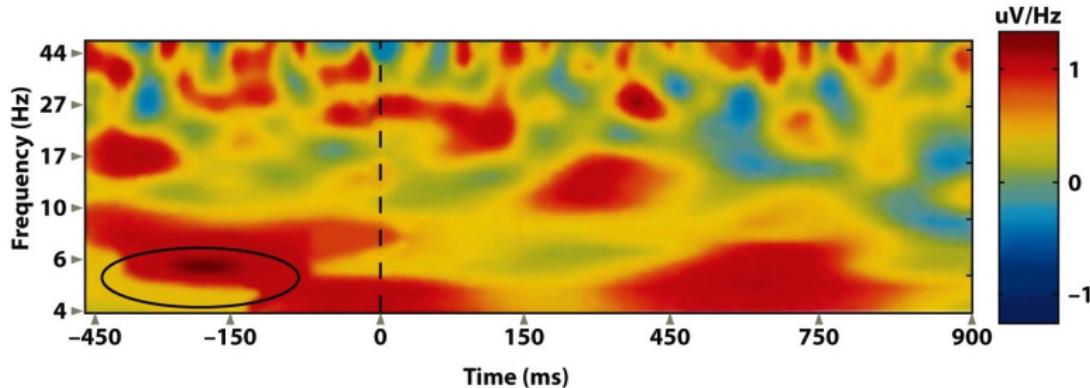


(Hagoort, Brown, & Groothusen, 1993)

Semantic Processing and the N400 Wave



Time-frequency analysis

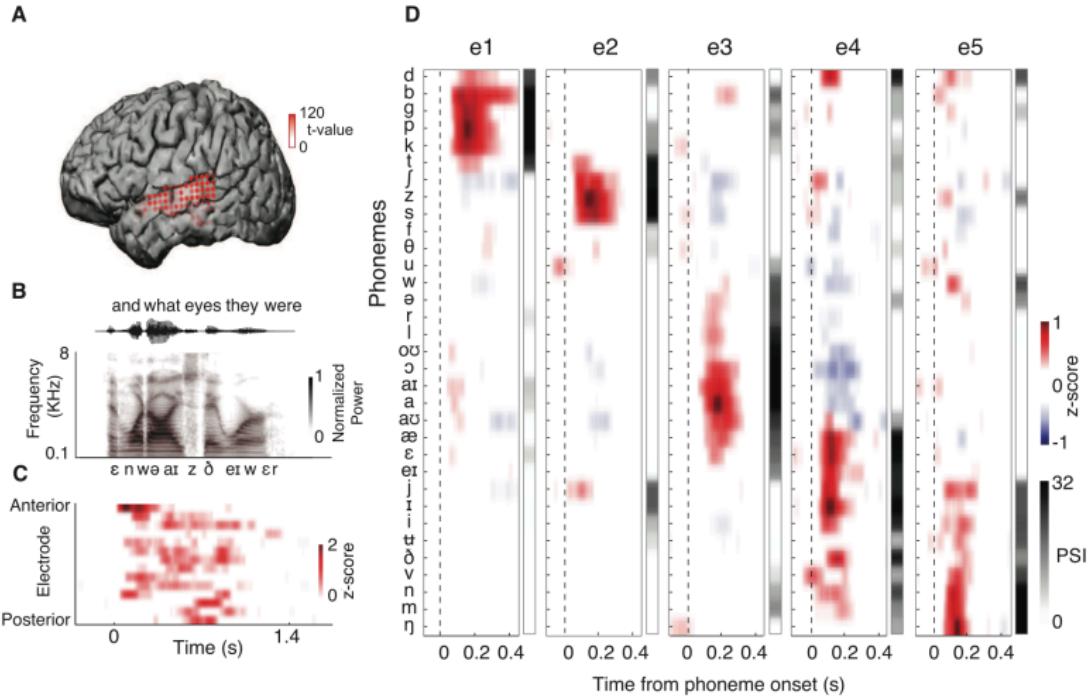


(Addante, Watrous, Yonelinas, Ekstrom, & Ranganath, 2011)

Studying Neural function

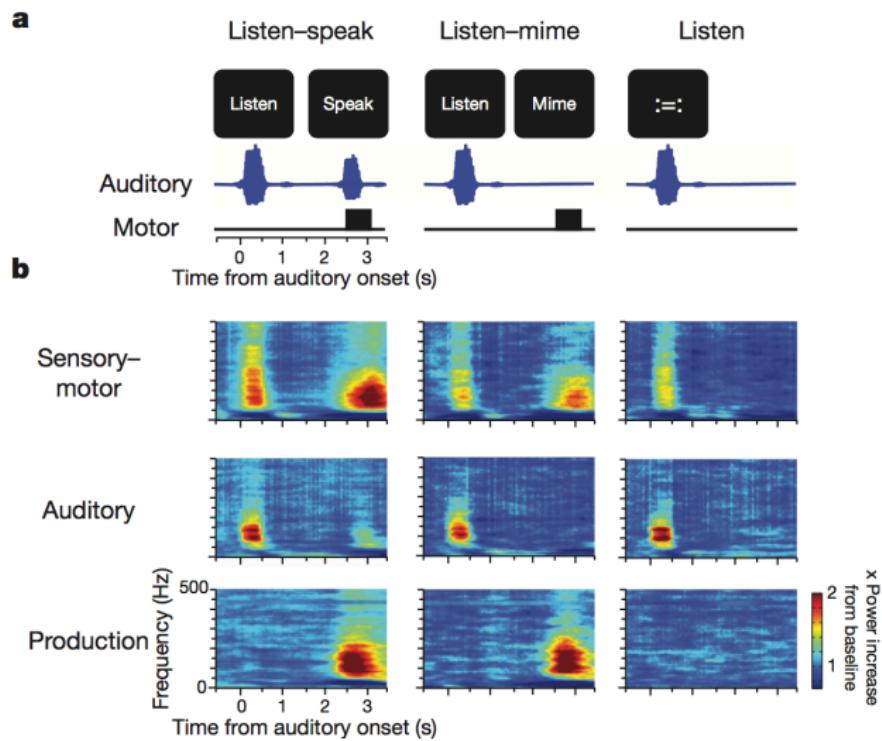
Electrocortogram

Electrocortogram



(Mesgarani, Cheung, Johnson, & Chang, 2014)

Electrocortogram



The complexity of neural signals

- 一个神经元可以有多达 1.5×10^4 个突触连接；
- 大脑皮层共包含约 2×10^{10} 个神经元细胞；
- 大脑皮层总共约有 2.4×10^{14} 个突触连接；
- 大脑皮层面积约 2.5×10^5 平方毫米；
- 每平方毫米大约有 10^5 个神经元和 10^9 个突触连接；

Analyzing the Brain Structure

Structural Analysis of the Brain

Structural Analysis of the Brain

- Computed Tomography (CT, 计算机断层扫描)

Structural Analysis of the Brain

- Computed Tomography (CT, 计算机断层扫描)
- Magnetic Resonance Imaging (MRI, 磁共振成像)

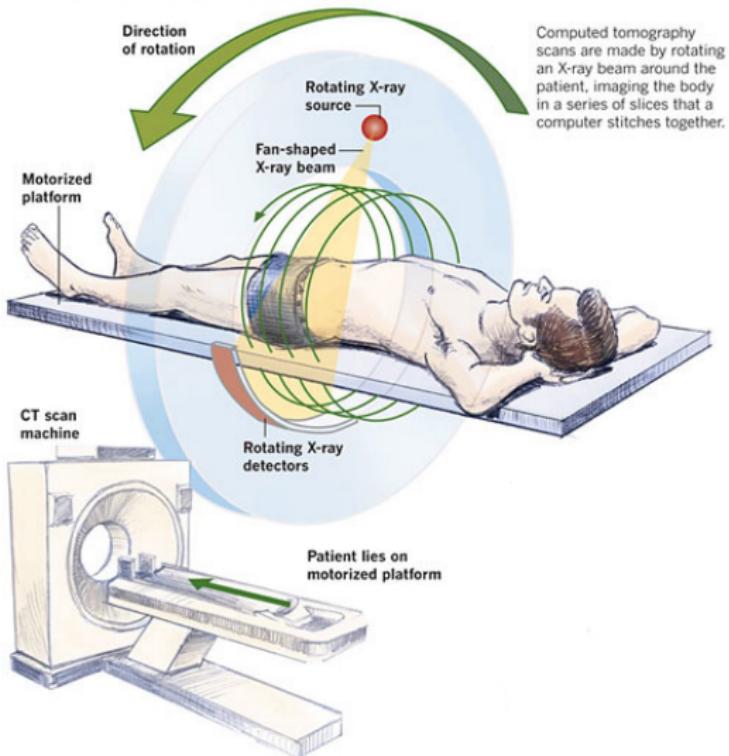
Structural Analysis of the Brain

- Computed Tomography (CT, 计算机断层扫描)
- Magnetic Resonance Imaging (MRI, 磁共振成像)
- Diffusion Tensor Imaging (DTI, 扩散张量成像)

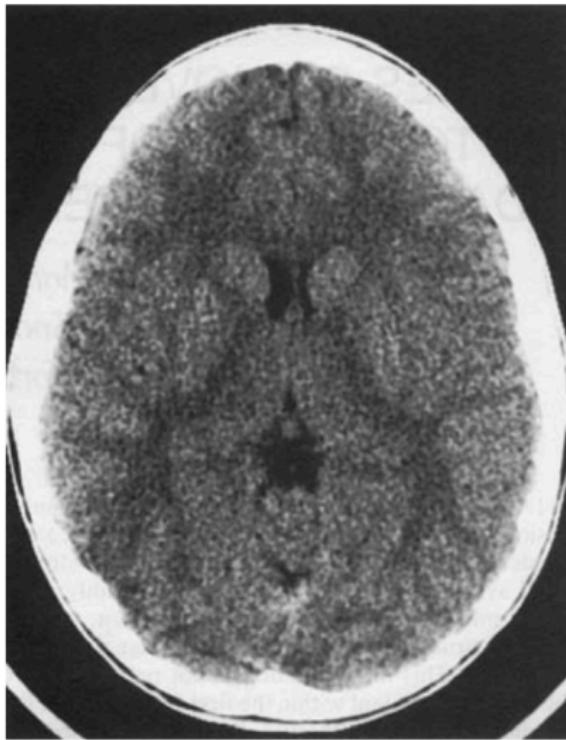
Analyzing the Brain Structure

Computed tomography (CT)

Computed tomography (CT)



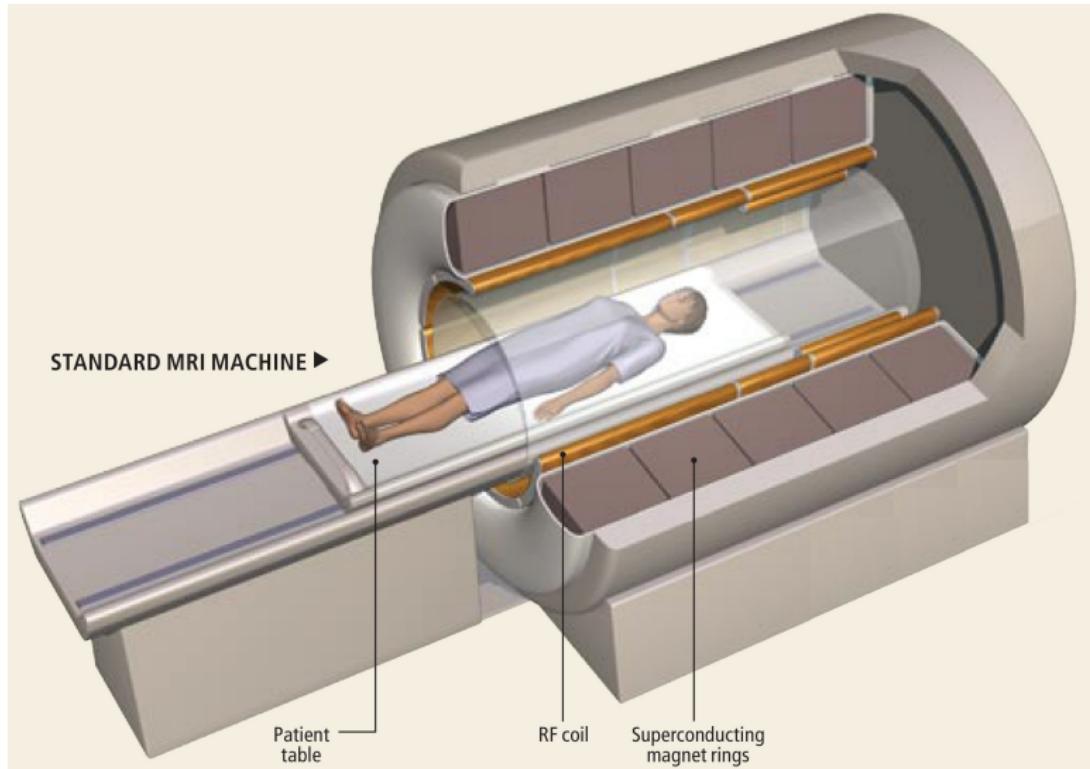
Computed tomography (CT)



Analyzing the Brain Structure

Magnetic Resonance Imaging

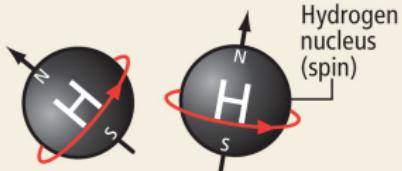
Magnetic Resonance Imaging



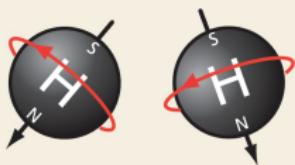
Magnetic Resonance Imaging

Creation of Nuclear Magnetization

① RANDOM ORIENTATION



Single, unpaired protons (here, hydrogen nuclei) spin on their axes along random orientations. The motion of the positively charged protons (known as spins) makes them act as if they are tiny bar magnets.

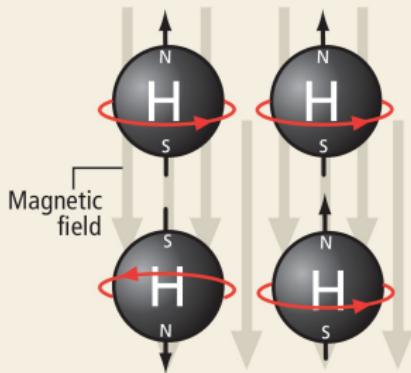


(Blümich, 2008)

Magnetic Resonance Imaging

Creation of Nuclear Magnetization

② MAGNETIZED SPINS ALIGN...



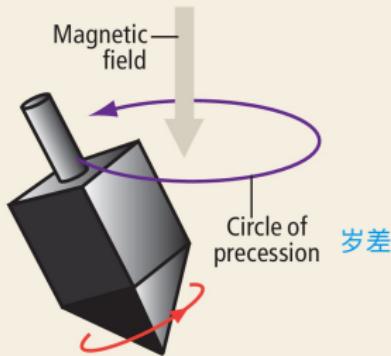
When the NMR machine applies a strong magnetic field to the sample, the spins (on average) tend to align their axes along the field lines.

(Blümich, 2008)

Magnetic Resonance Imaging

Creation of Nuclear Magnetization

③ ... AND PRECESS LIKE TOPS



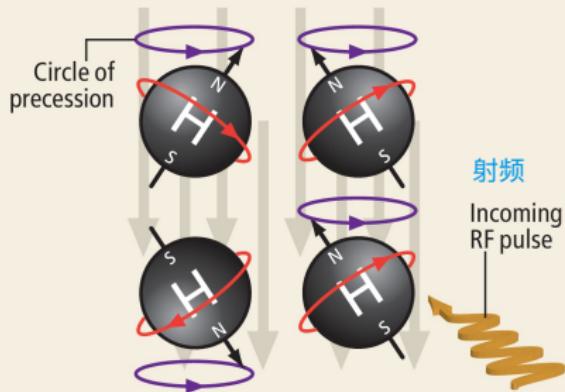
The alignment is inexact, though, resulting in precession—the axes rotate around the field lines—at a frequency that is unique for each type of nucleus and chemical group in a molecule.

(Blümich, 2008)

Magnetic Resonance Imaging

RF Energy Absorption and Release

① MAGNETIZED SPIN GROUP



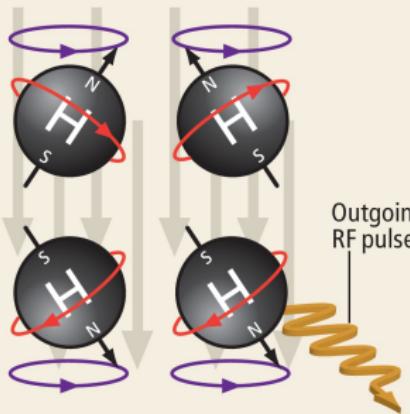
Magnetized spins precess along random orientations in the magnetic field. When a coil in the NMR machine sends an RF pulse toward the group, only a spin that precesses at a rate and phase that matches the pulse's frequency can absorb its energy.

(Blümich, 2008)

Magnetic Resonance Imaging

RF Energy Absorption and Release

② SPIN HAS ABSORBED RF ENERGY



Absorption causes the spin to flip 180 degrees. All nuclei that interact with the RF pulse in the same way absorb its energy and flip 180 degrees. The machine's coil picks up the signal induced by the magnetization caused by these changes in spin

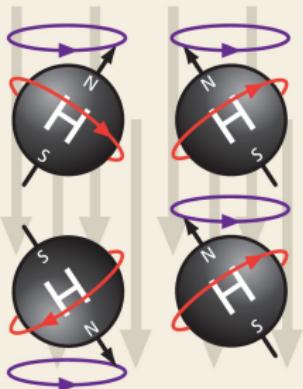
Outgoing
RF pulse

(Blümich, 2008)

Magnetic Resonance Imaging

RF Energy Absorption and Release

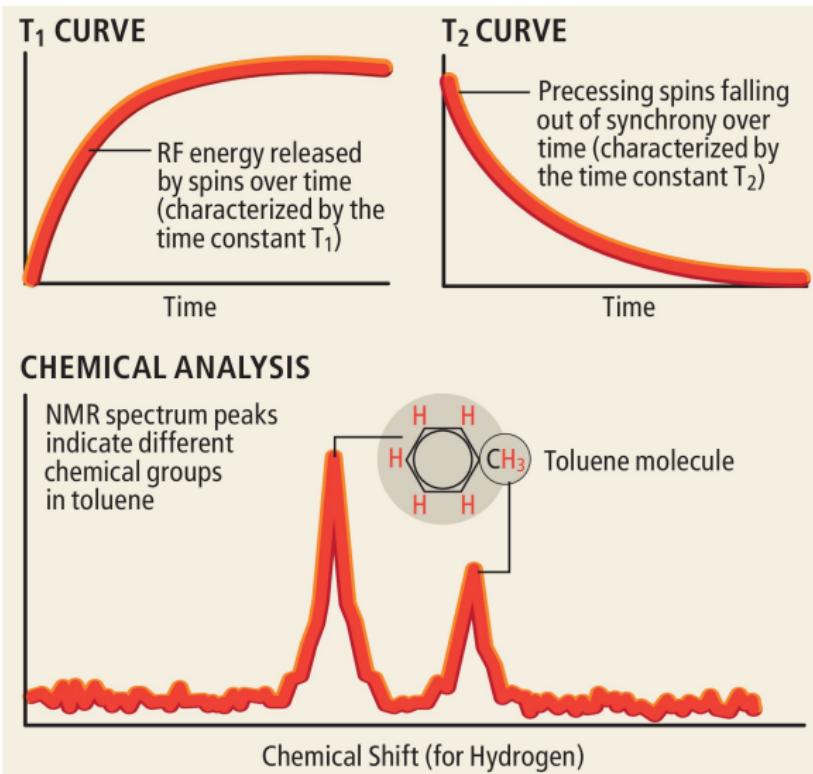
③ SPIN HAS RELEASED RF ENERGY



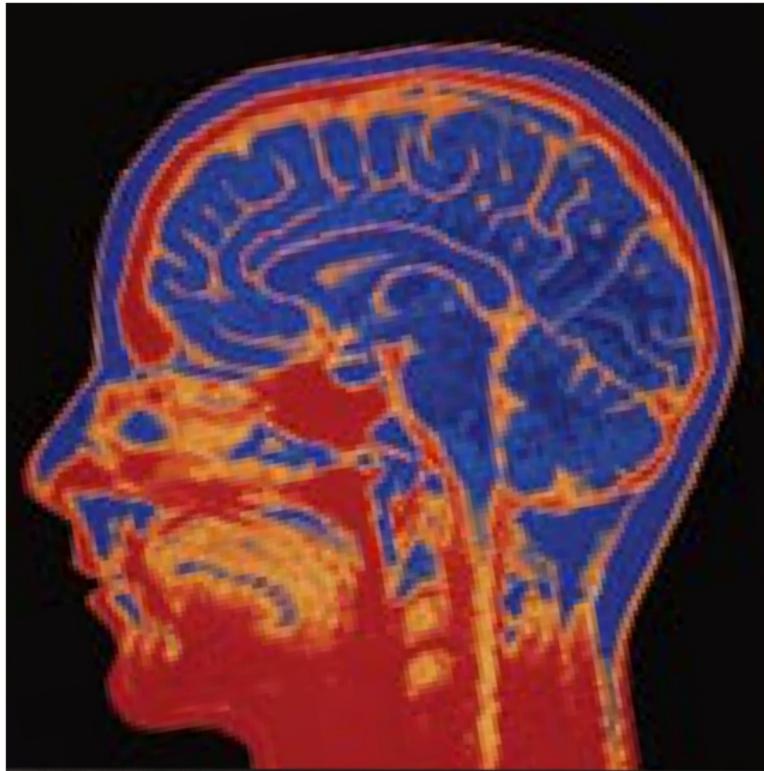
At random intervals, flipped spins release the absorbed RF energy and return to their original (prepulse) orientations.

(Blümich, 2008)

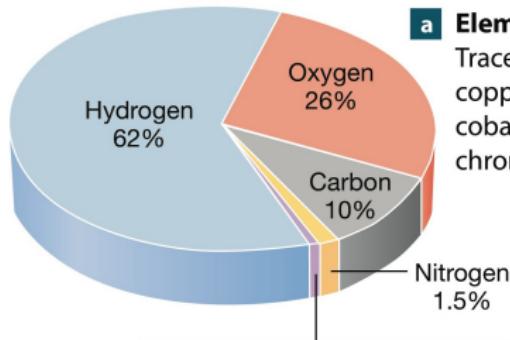
Magnetic Resonance Imaging



Magnetic Resonance Imaging



Elemental composition of the body



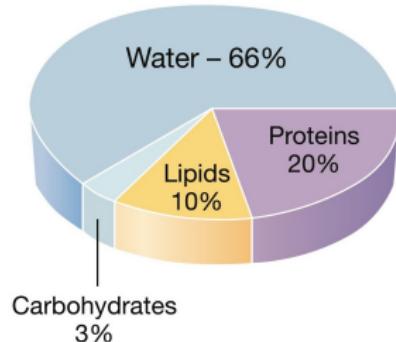
a Elemental composition of the body.

Trace elements include silicon, fluorine, copper, manganese, zinc, selenium, cobalt, molybdenum, cadmium, chromium, tin, aluminum, and boron.

OTHER ELEMENTS

Calcium	0.2%
Phosphorus	0.2%
Potassium	0.06%
Sodium	0.06%
Sulfur	0.05%
Chlorine	0.04%
Magnesium	0.03%
Iron	0.0005%
Iodine	0.0000003%
Trace elements	(see caption)

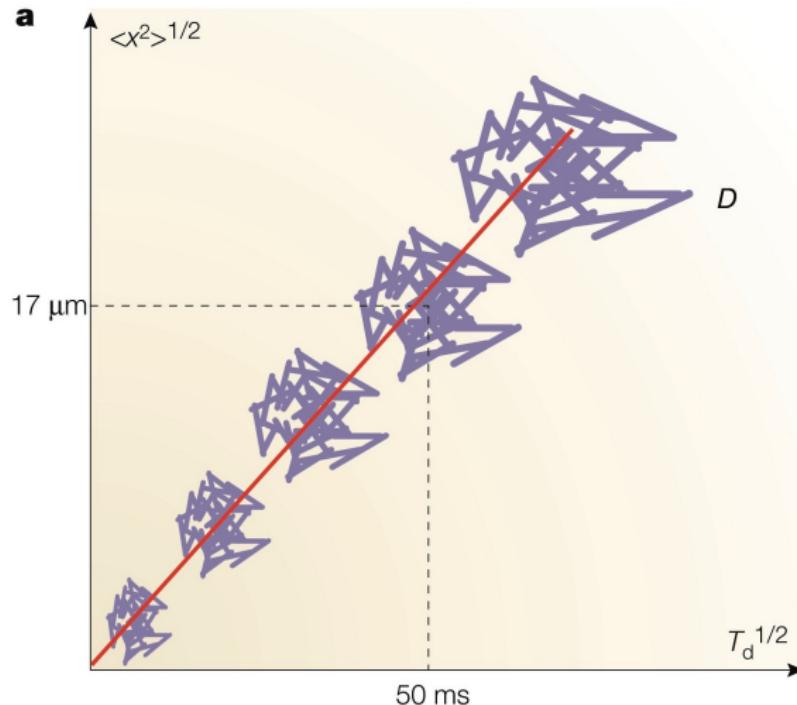
b Molecular composition of the body.



Analyzing the Brain Structure

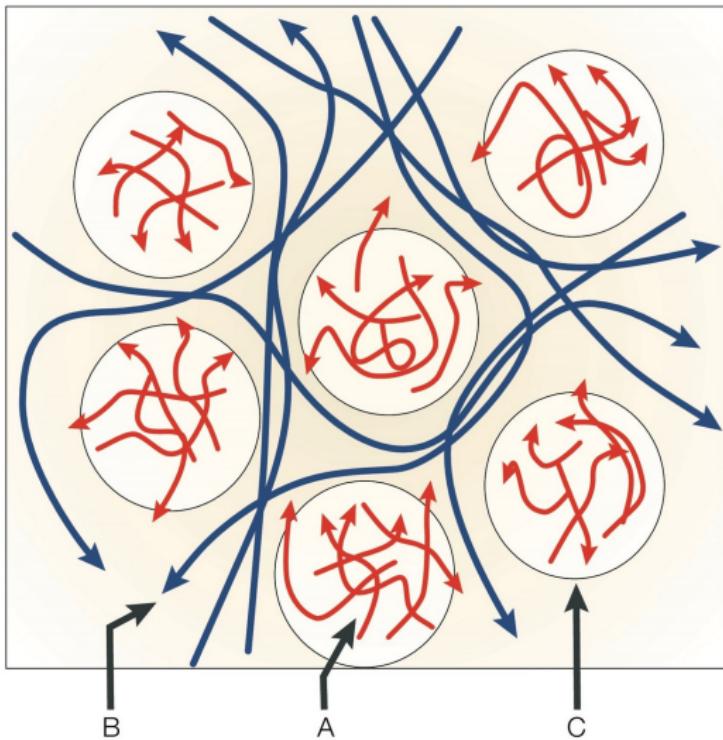
Diffusion Tensor Imaging

Diffusion Tensor Imaging

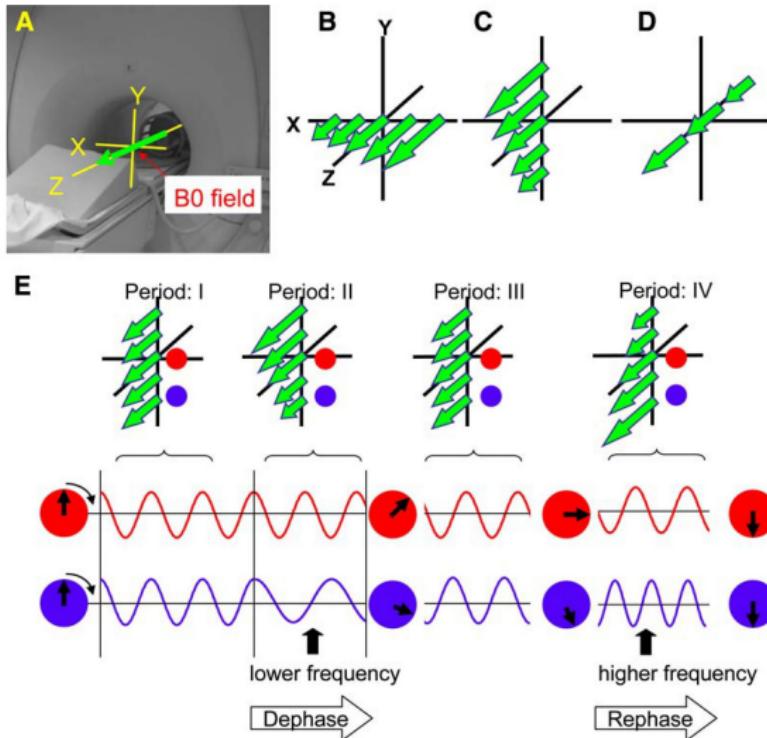


Diffusion Tensor Imaging

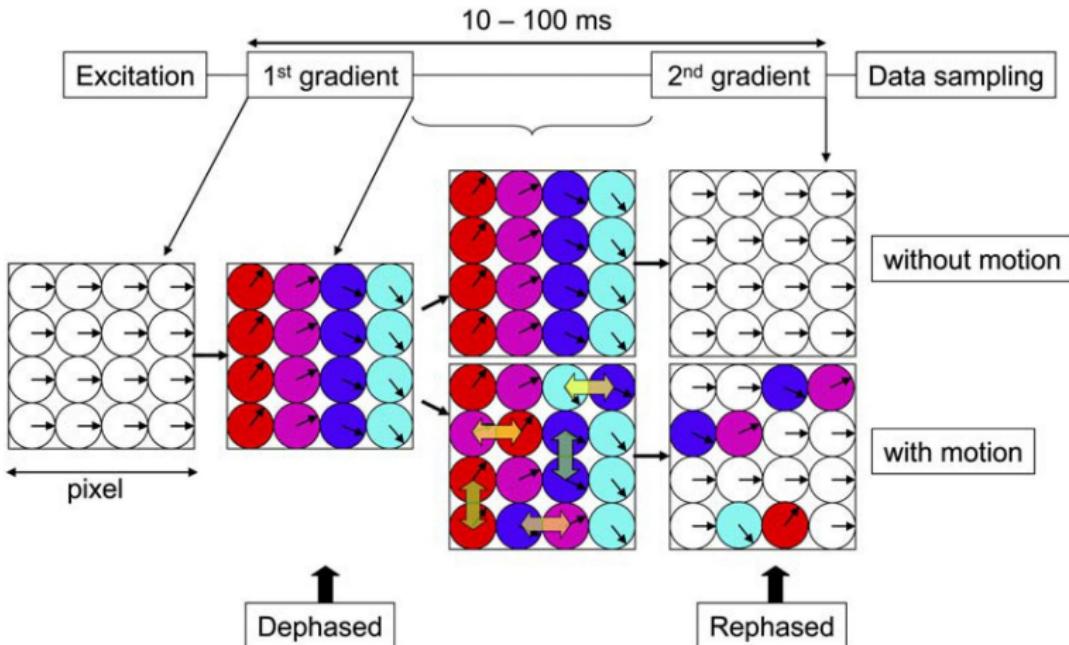
b



Diffusion Tensor Imaging

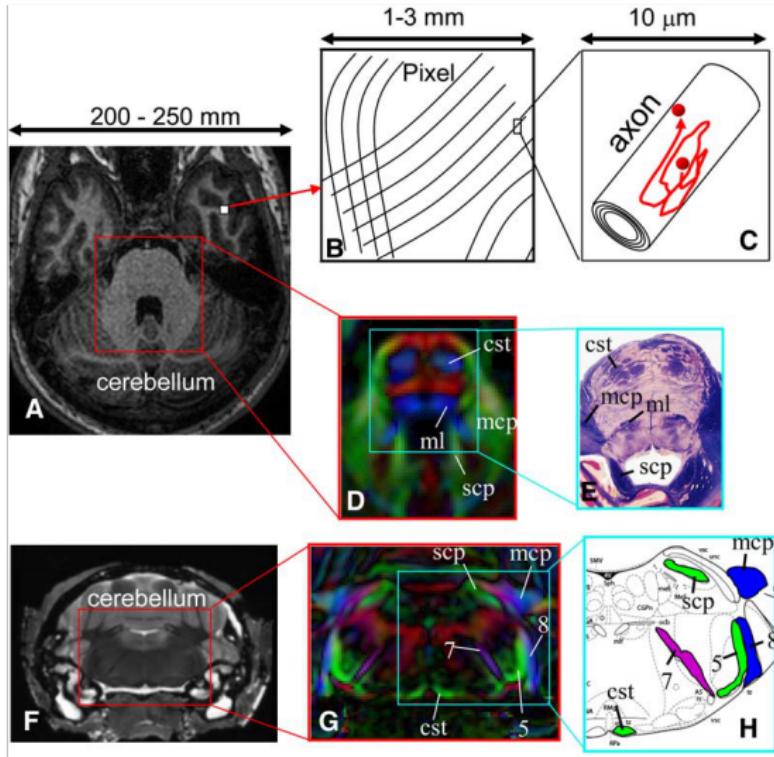


Diffusion Tensor Imaging

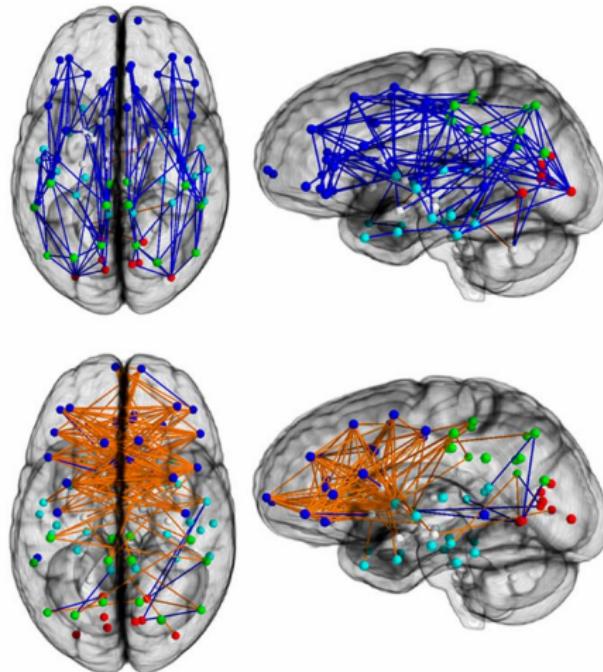


(Mori & Zhang, 2006)

Diffusion Tensor Imaging

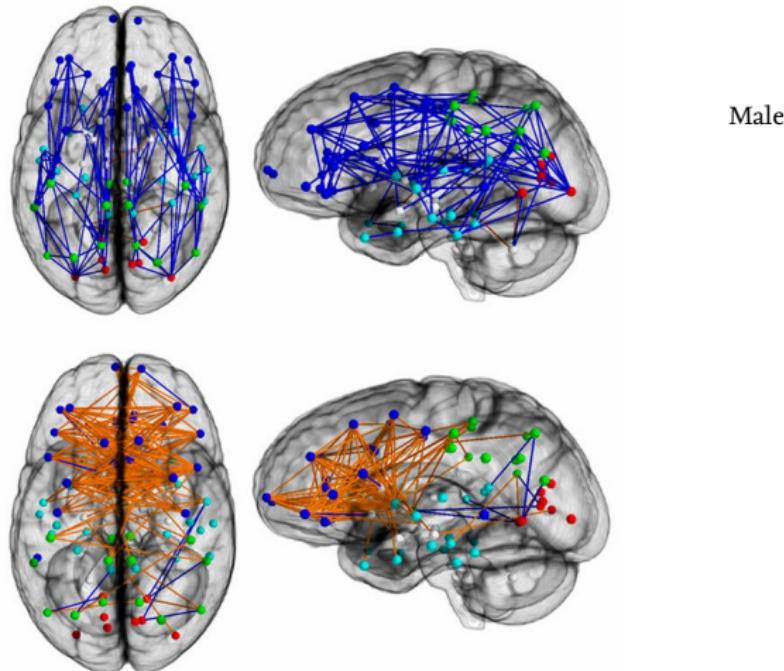


Diffusion Tensor Imaging: Sex differences



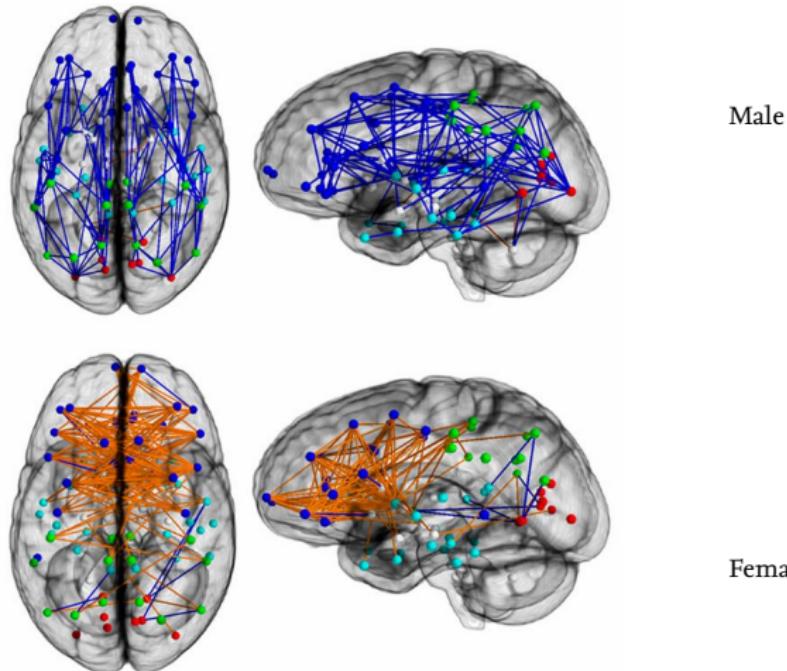
(Ingalhalikar et al., 2013)

Diffusion Tensor Imaging: Sex differences



(Ingalhalikar et al., 2013)

Diffusion Tensor Imaging: Sex differences



(Ingalhalikar et al., 2013)

Neuroimaging: Function + Structure

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- Positron Emission Tomography
(PET, 正电子断层扫描术)

Neuroimaging: Function + Structure

- Positron Emission Tomography
(PET, 正电子断层扫描术)
- functional Magnetic Resonance Imaging
(fMRI, 功能性磁共振成像)

Neuroimaging: Function + Structure

- Positron Emission Tomography
(PET, 正电子断层扫描术)
- functional Magnetic Resonance Imaging
(fMRI, 功能性磁共振成像)
- functional near-infrared spectroscopy
(fNIRS, 功能近红外光谱成像技术)

Neuroimaging: Function + Structure

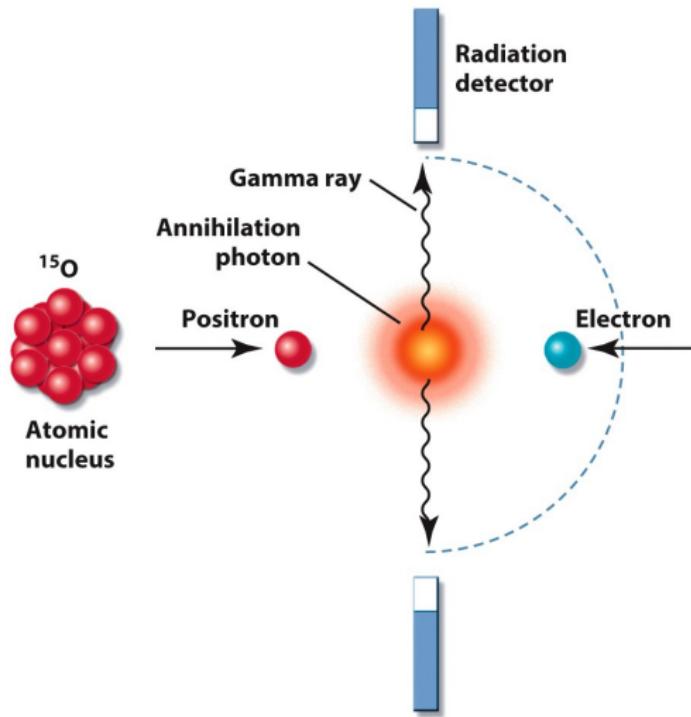
Positron Emission Tomography

Positron Emission Tomography

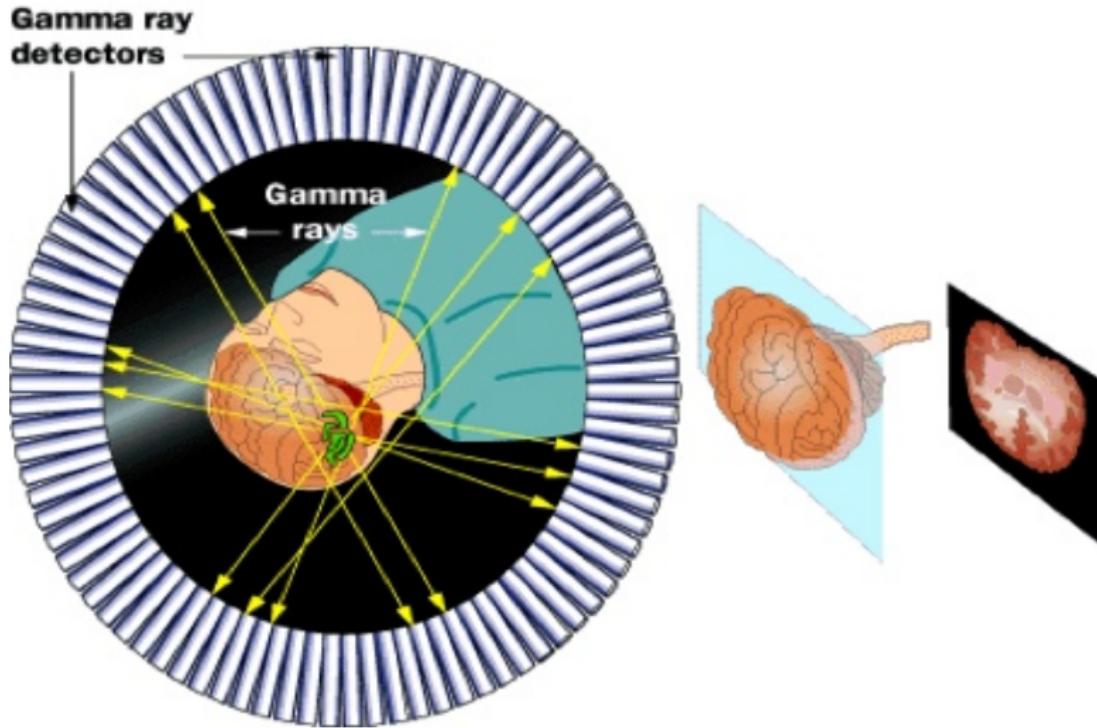


Positron Emission Tomography

Positron Emission Tomography

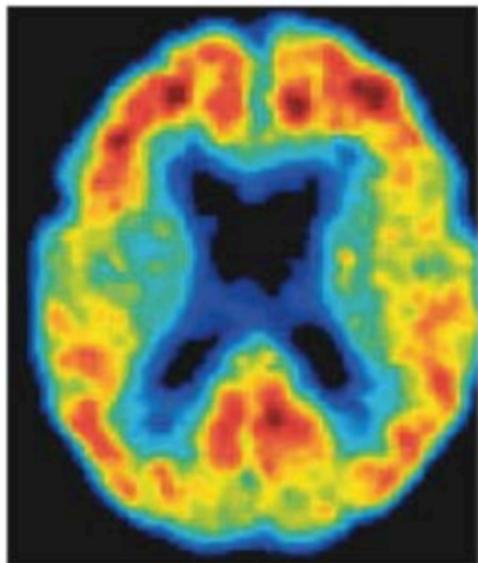


Positron Emission Tomography



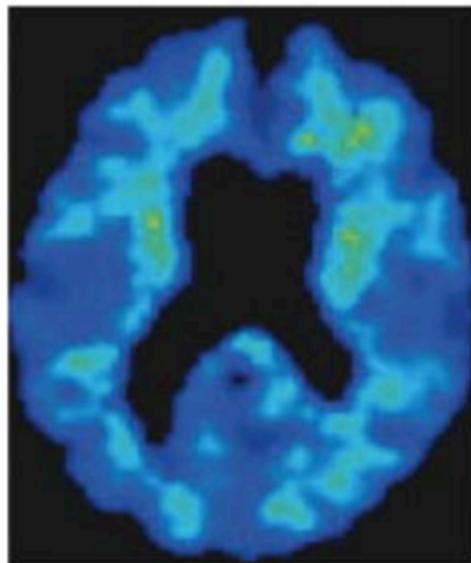
Using PiB to look for signs of Alzheimer's disease

Alzheimer's



a

Control



b

(Vitali, Migliaccio, Agosta, Rosen, & Geschwind, n.d.)

Neuroimaging: Function + Structure

Functional Magnetic Resonance Imaging

BOLD signals

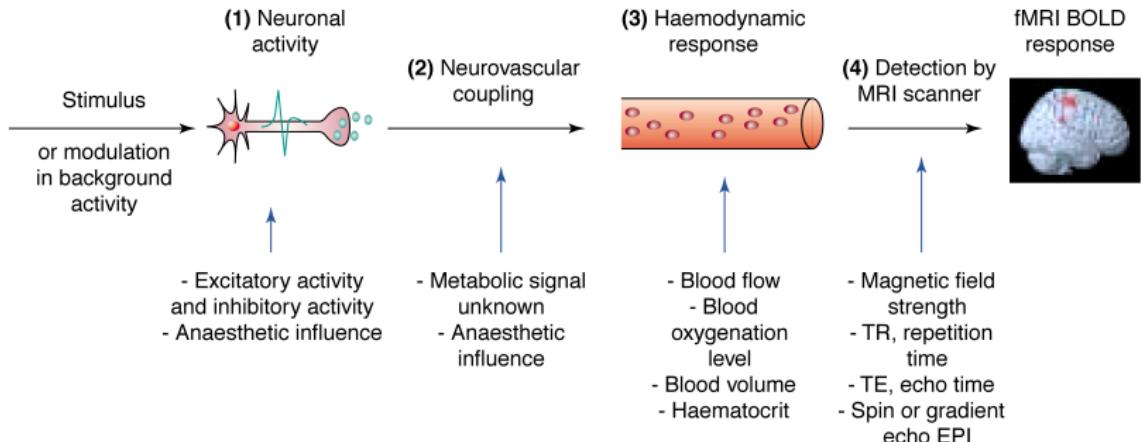
BOLD signals

- Deoxygenated hemoglobin (脱氧血红蛋白) is paramagnetic (i.e., weakly magnetic in the presence of a magnetic field), whereas oxygenated hemoglobin (含氧血红蛋白) is not.

BOLD signals

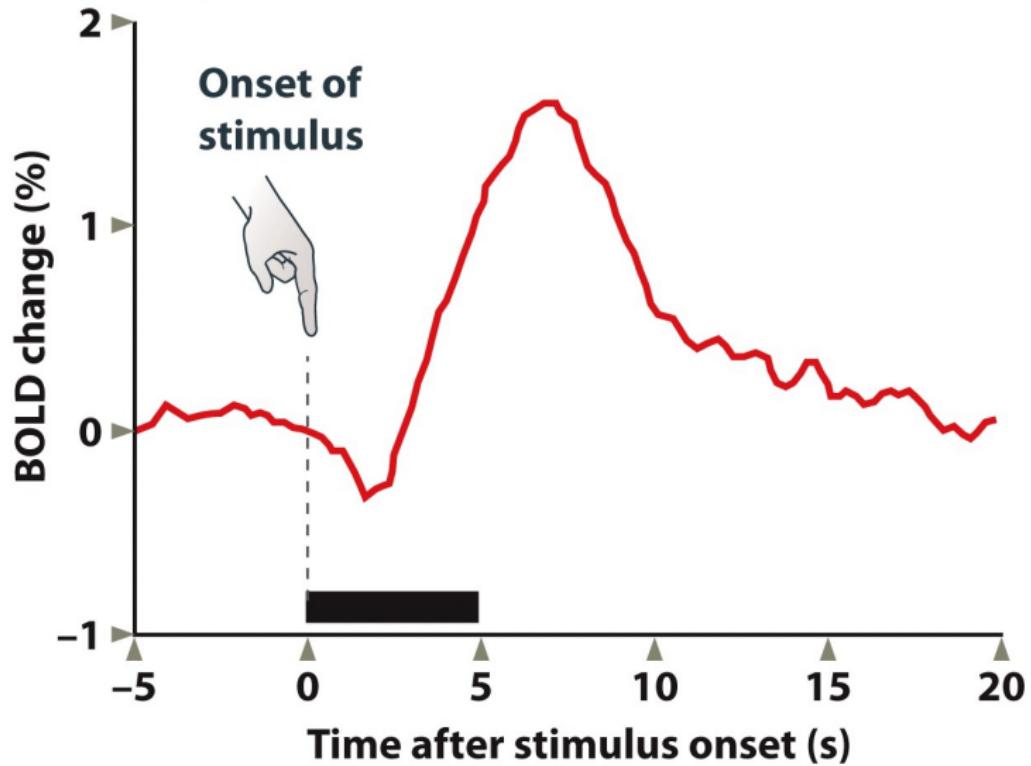
- Deoxygenated hemoglobin (脱氧血红蛋白) is paramagnetic (i.e., weakly magnetic in the presence of a magnetic field), whereas oxygenated hemoglobin (含氧血红蛋白) is not.
- fMRI detectors measure the ratio of oxygenated to deoxygenated hemoglobin; this value is referred to as the blood oxygen level—dependent (血氧水平依赖), or BOLD.

Functional Magnetic Resonance Imaging



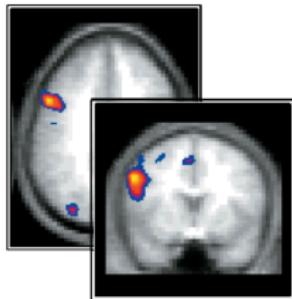
(Arthurs & Boniface, 2002)

Stimulus and BOLD signals



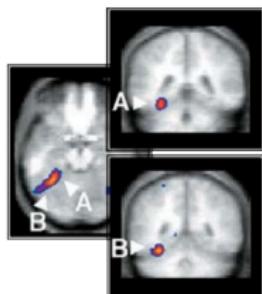
Encode or retrieve

Posterior LIFG

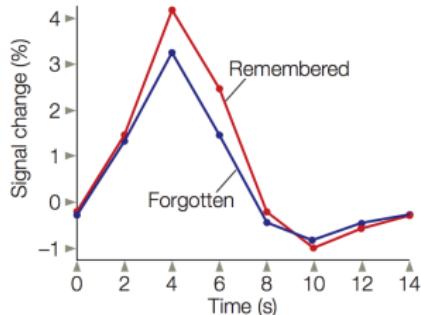
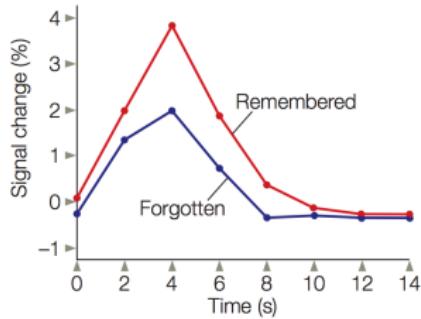


a

Parahippocampal/fusiform gyrus



b

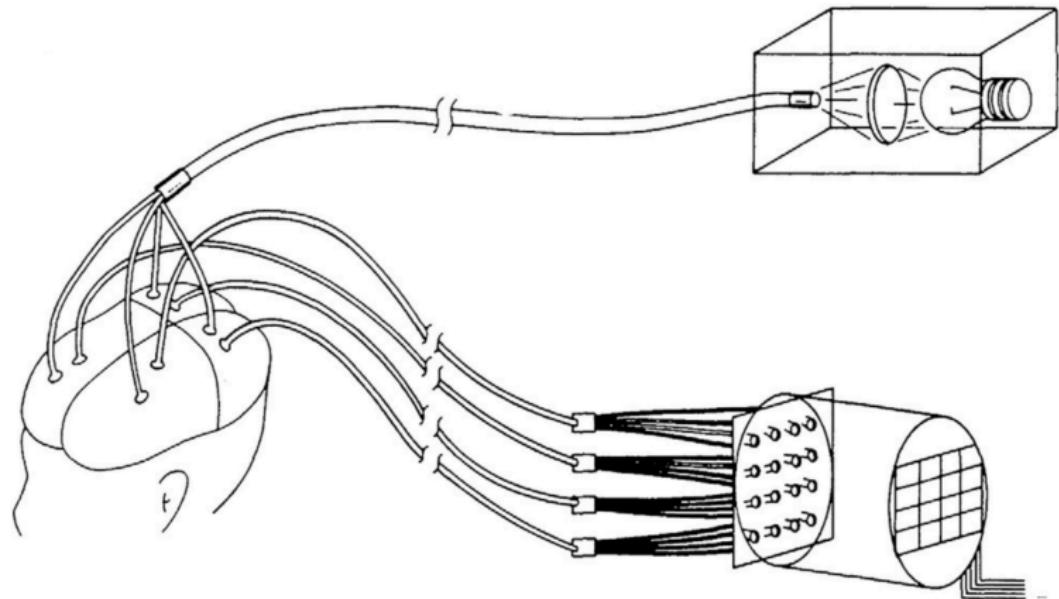


(A. D. Wagner et al., 1998)

Neuroimaging: Function + Structure

functional Near-Infrared Spectroscopy

functional Near-Infrared Spectroscopy



(Ferrari & Quaresima, 2012)

functional Near-Infrared Spectroscopy

functional Near-Infrared Spectroscopy

- fNIRS is a non-invasive imaging method involving the quantification of chromophore concentration resolved from the measurement of near infrared (NIR) light attenuation or temporal or phasic changes.

functional Near-Infrared Spectroscopy

- fNIRS is a non-invasive imaging method involving the quantification of chromophore concentration resolved from the measurement of near infrared (NIR) light attenuation or temporal or phasic changes.
- NIR spectrum light takes advantage of the optical window in which skin, tissue, and bone are mostly transparent to NIR light in the spectrum of 700-900 nm, while hemoglobin (oxy-Hb) and deoxygenated-hemoglobin (deoxy-Hb) are stronger absorbers of light.

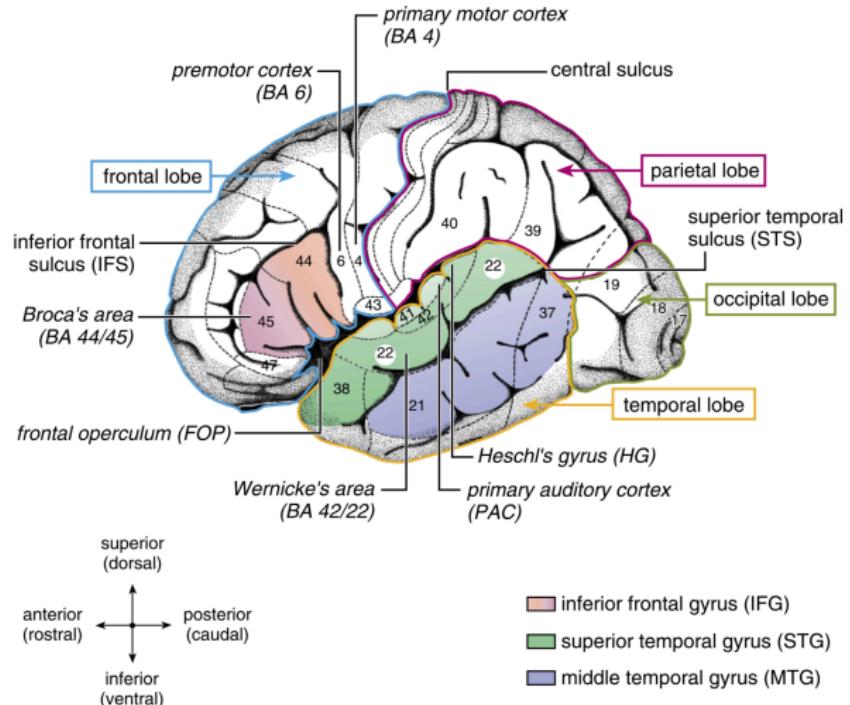
functional Near-Infrared Spectroscopy

- Differences in the absorption spectra of deoxy-Hb and oxy-Hb allow the measurement of relative changes in hemoglobin concentration through the use of light attenuation at multiple wavelengths.

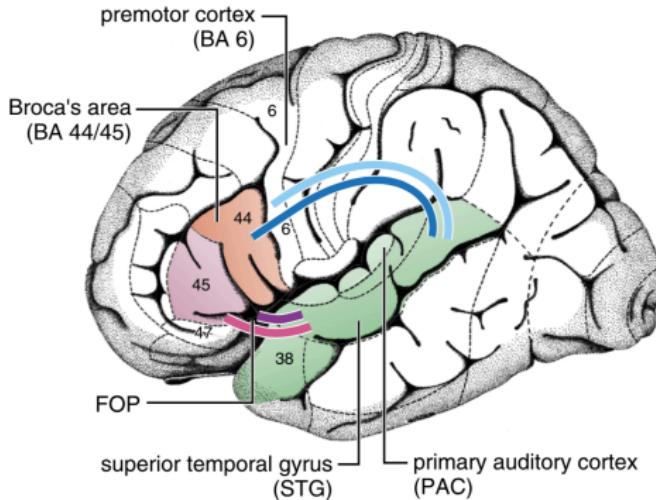
Neuroimaging: Function + Structure

Applying to language

The left hemisphere



Structural connectivities



Dorsal Pathway I

■ pSTG to premotor cortex
via AF/SLF

Dorsal Pathway II

■ pSTG to BA 44
via AF/SLF

Ventral Pathway I

■ STG to BA 45
via EFCS

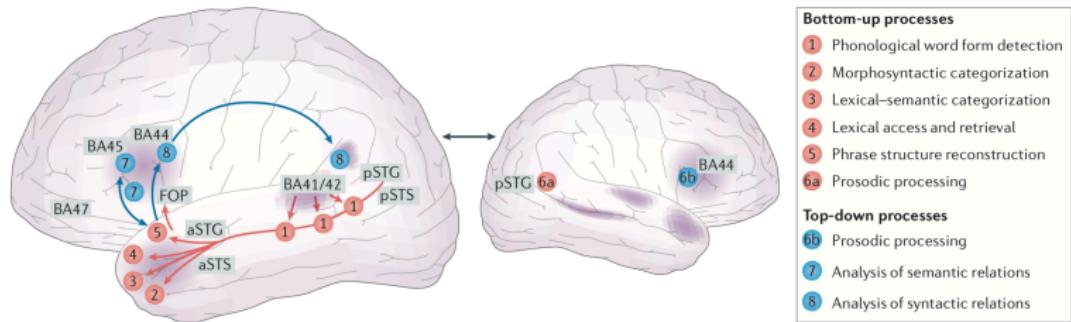
Ventral Pathway II

■ antSTG to FOP
via UF

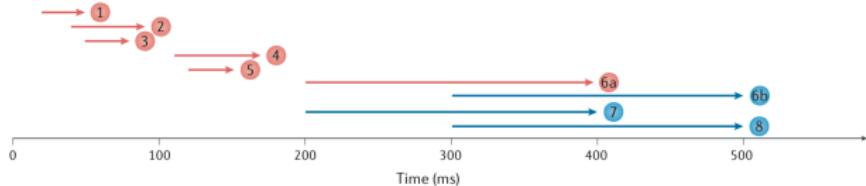
(Friederici, 2011)

The adult auditory language comprehension network

a Language comprehension in adults

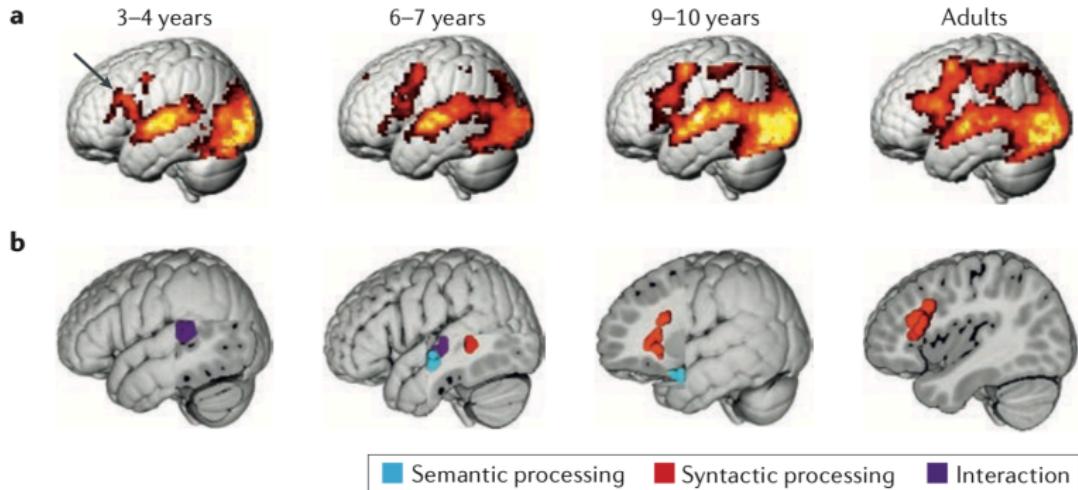


b



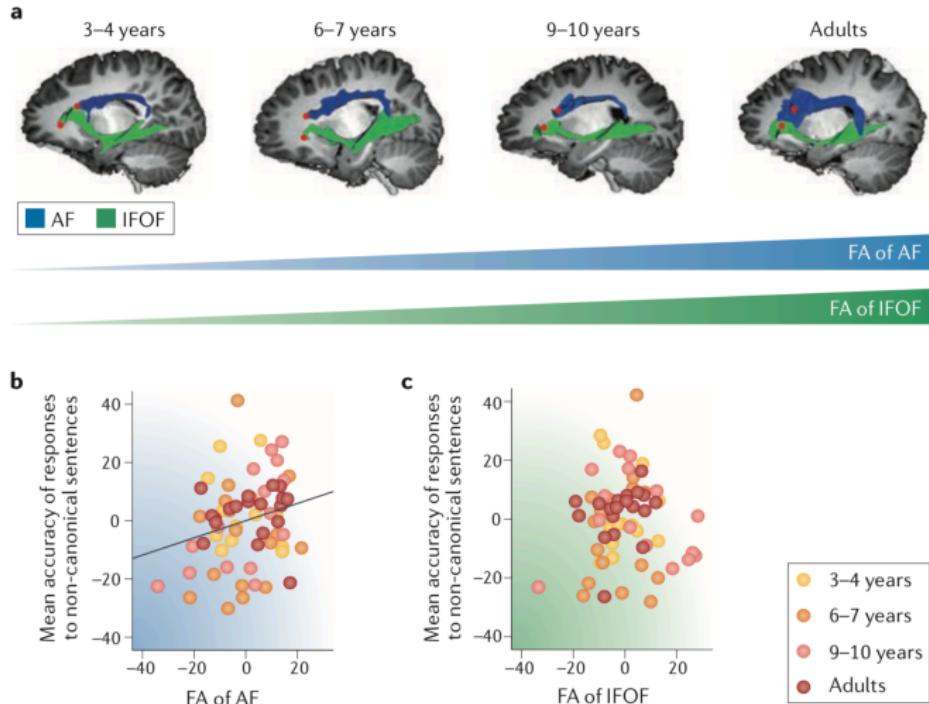
(Skeide & Friederici, 2016)

The segregation of syntax from semantics



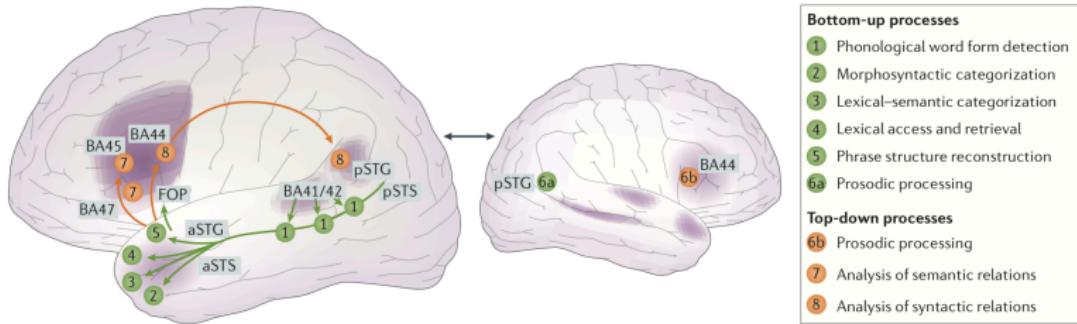
(Skeide & Friederici, 2016)

The ontogenetic emergence of complex syntax

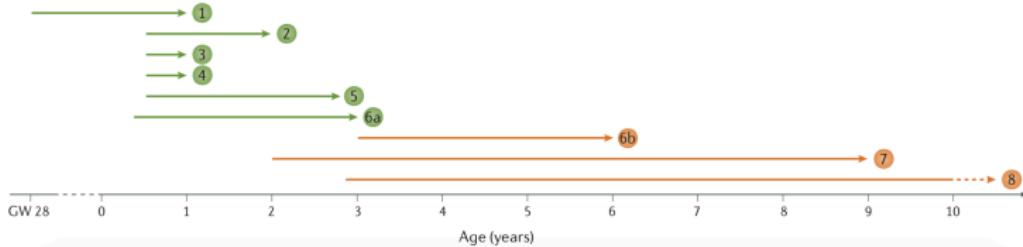


The evolving cortical circuit

a Developmental trajectories of language and comprehension



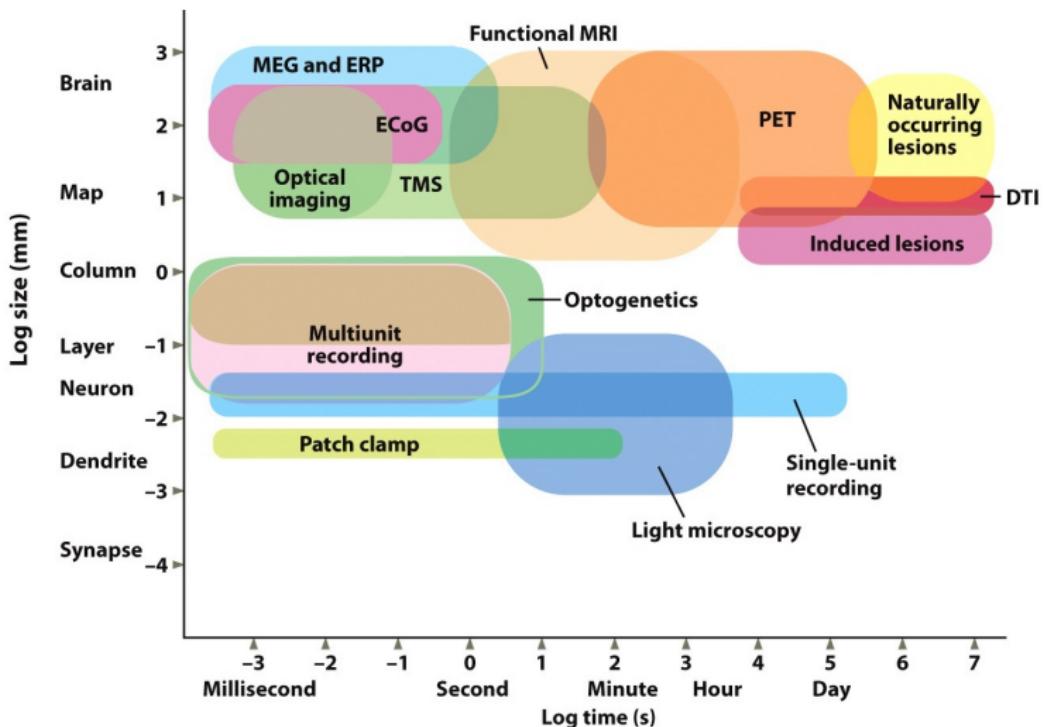
b



(Skeide & Friederici, 2016)

Summary

Summary



Thank you

References

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