第二章
认知神经科学简介

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第二节 认知神经科学

1. 什么是认知神经科学
2. 中枢神经系统
3. 神经生理学探测技术

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什么是认知神经科学

- 认知神经科学
  = 认知心理学 + 神经科学
- 对神经科学和认知心理学之间关系的研究，尤其是涉及记忆、感觉和知觉、问题解决、语言加工、运动功能和认知活动的那些关于心灵的理论。

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- 认知心理学和神经科学互相支持：

1、为心灵的理论构想寻找来自大脑的物质证据

认知心理学 ⇄ 神经科学

2、将神经科学的发现与对脑和认知的更全面的理论模型联系起来

3. 临床上试图探寻脑的病理机制和行为之间的关联
4. 将神经功能增加到心灵理论的模型中
5. 通过开发与人脑运行方式相同的计算机模型来模拟人的认知
6. 技术的进步使得科学家能够深入探究人脑内部并揭示出前所未闻的结构和过程

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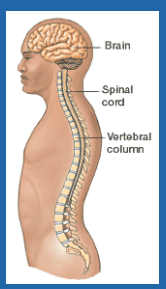
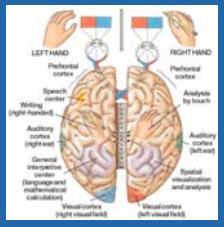
中枢神经系统

- 中枢神经系统包括：脑和脊髓
  - 仅重约1350克
  - 比台灯还省电（大脑12-20瓦，电脑休眠10瓦，运行150瓦）





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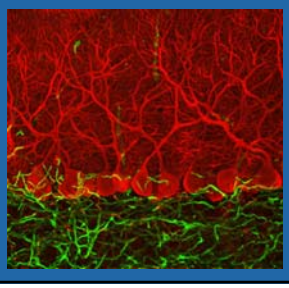
- 神经元
  - 中枢神经系统的基本单元
  - 人脑约有1000亿个神经元



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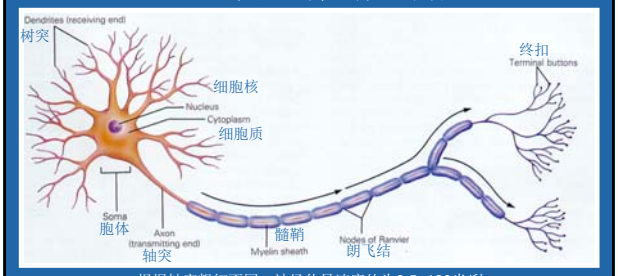
神经元
- 胞体
- 突起
  - 树突：接收神经冲动
  - 轴突：传递神经冲动



- 根据轴突粗细不同，神经传导速度约为0.5~120米/秒

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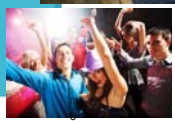
Cognitive Neuroscience in Everyday Life

Myelination (髓鞘化)

- the **prefrontal cortex (PFC)** is among the last regions of the brain to fully myelinate as humans move into **young adulthood**
- **teenagers** are statistically more likely to engage in risky behavior, and will typically be more impulsive and unpredictable
- many automobile rental companies won't rent to individuals younger than 22
- in many parts of the United States it is illegally for individuals younger than 21 to purchase alcohol



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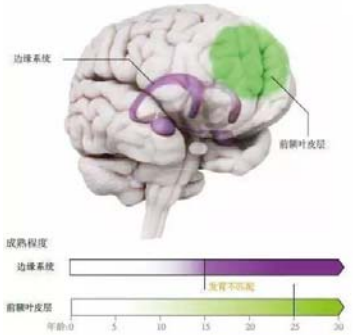

边缘系统&前额叶之间的不匹配：青少年的情绪化是边缘系统造成的，而前额叶皮层的控制功能要到25岁左右才完全成熟，这中间有近十年的时间，情绪冲动和深思熟虑之间处于失衡状态。

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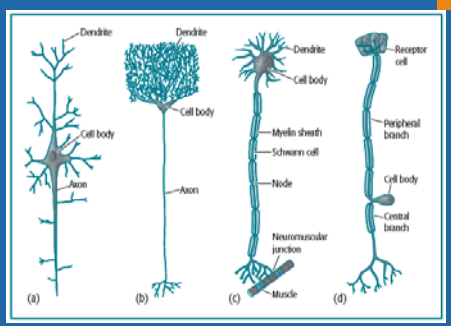

a. 锥体细胞；b.小脑的浦肯野细胞； c.运动神经元； d. 感觉神经元

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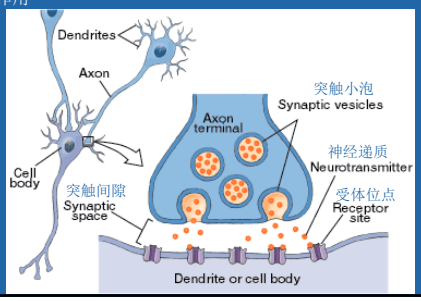
- 突触——神经元之间的传导
  - 突触间隙：树突和轴突之间并非紧密相连，而是留有间隙
  - 轴突释放神经递质，改变树突的极性或者电位，产生兴奋或者抑制的作用



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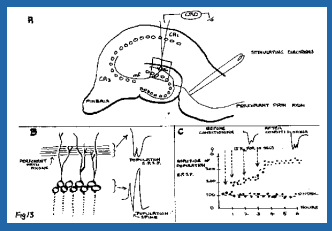
Electroencephalography, EEG脑电图

Event-related potential, ERP事件相关电位



Single-cell recording单细胞记录

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Video

- video\neuron.mp4
- video\synapse transmission.mp4

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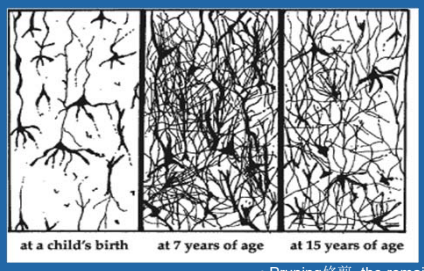
Neural networks from birth to 15 years of age



- Most neuron are present
- Not all synaptic connections and myelination are complete
- Pruning修剪, the remaining "wiring" is more powerful and efficient
- Receive 1000 synapses from and send synapses to 1000 other neuron

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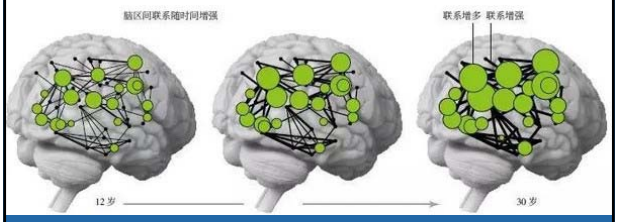

青少年大脑最显著的变化不是脑区的成长，而是神经元集群之间交流的增多。用图论分析技术分析磁共振成像扫描数据，显示从12岁到30岁期间，特定脑区或神经元集群之间的联系会变强（黑线变粗）。同时，某些特定区域内的联系会增多（绿圈变大）。这些变化最终将帮助大脑成熟，并胜任复杂思考和社会交际。

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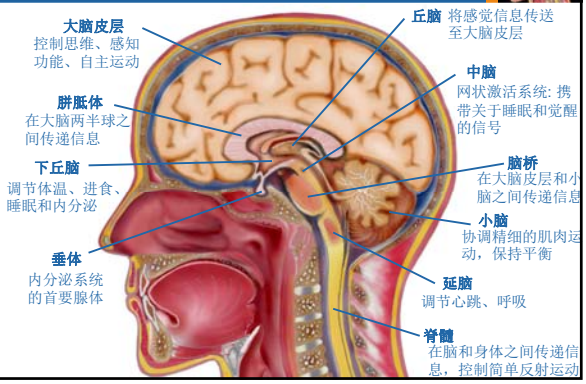
脑的解剖结构



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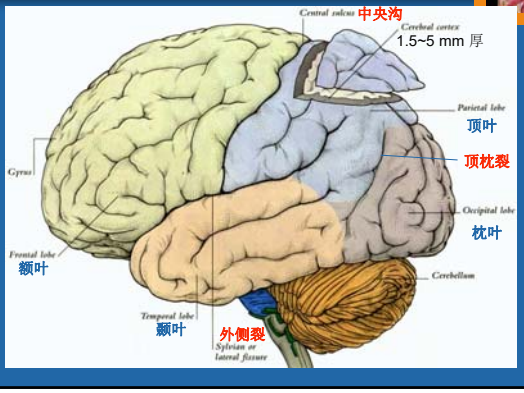
人类大脑皮层的主要分区



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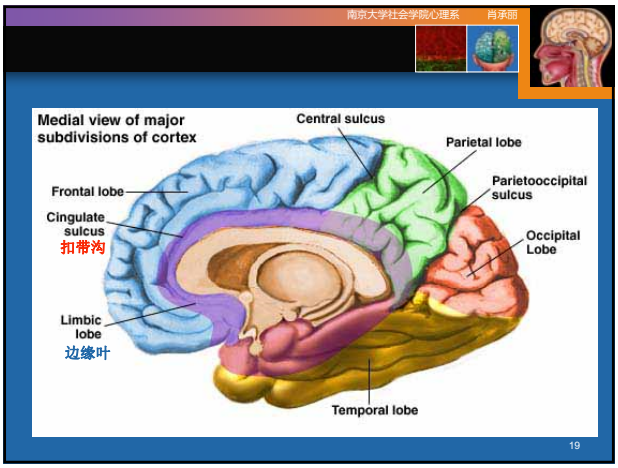

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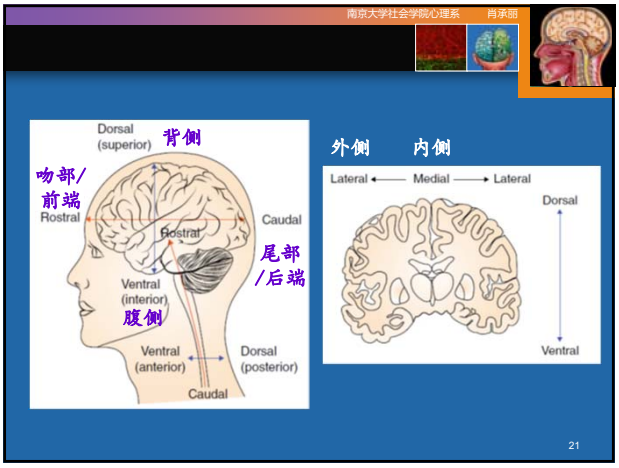

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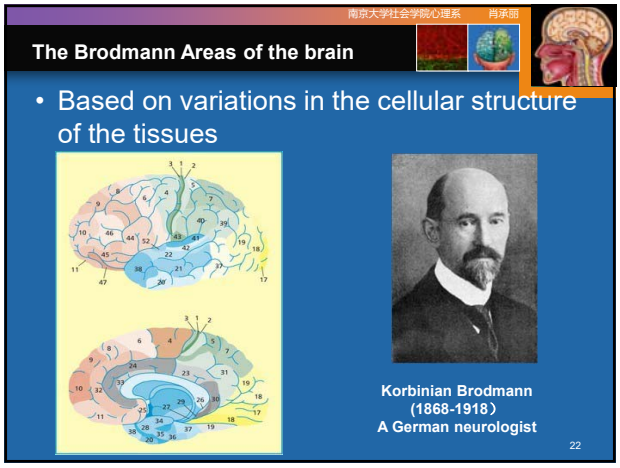

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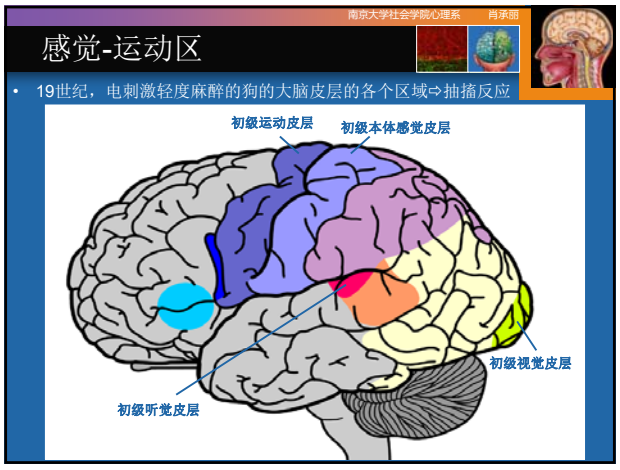

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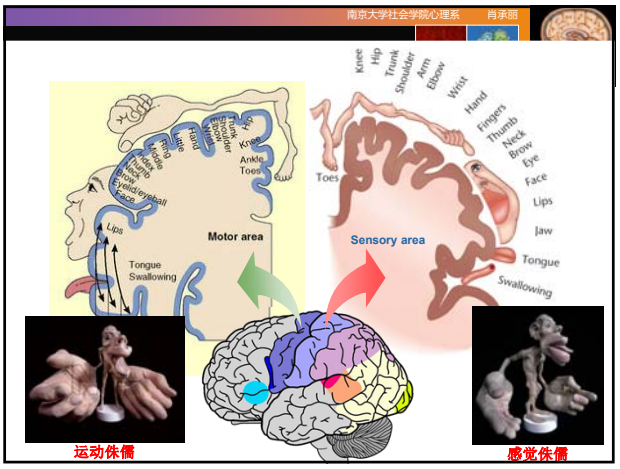

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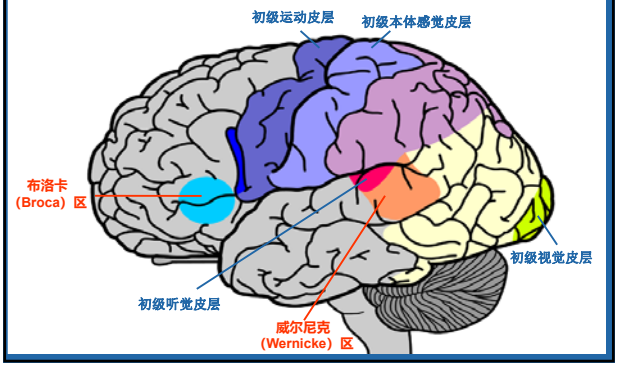
言语功能的关键脑区（左侧）



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- 布洛卡区
  - 十九世纪60年代，法国神经病学家布洛卡(Pierre Paul Broca)对失语症患者的脑部进行死后检查发现有一个脑区受损
  - 患者说话短促，不合语法

“为什么，是的……星期四，呃，呃，呃，不，呃，星期五……芭 —芭 — 拉……妻子……和，哦，车……开……收费高速公路……你知道……休息和……电视”

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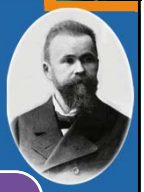
- 威尔尼克区
  - 1876年，德国神经病学家威尔尼克(Karl Wernicke) 描述了一种新型的失语症
  - 患者说得相当符合语法，但却几乎没有意义



“哦，我在出汗，我太紧张了，你知道，有时我被抓住，我不能说出tarripoi，一个月前，差不多吧，我做了好多，我施加很多影响，哦，还有，你知道我说的是什么，我必须来回跑，仔细检查，trebbin和所有那些玩意。”

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相关性神经成像方法

- EEG & ERP
  - Electroencephalography 脑电图
  - Event-related potential 事件相关电位
- PET Scans
  - Positron emission tomography正电子发射计算机断层显像
- MRI & fMRI
  - (functional) magnetic resonance imaging （功能性）磁共振成像
- MEG
  - Magnetoencephalography 脑磁图
- fNIRS
  - functional near-infrared spectroscopy功能性近红外光谱技术

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脑电图（EEG）和事件相关电位（ERP）

- 记录头皮上的电位
  - 当一大群神经元激活时，它们的电活动会在头皮上产生独特的电位模式
- 有很高的时间分辨率
- 空间分辨率较差

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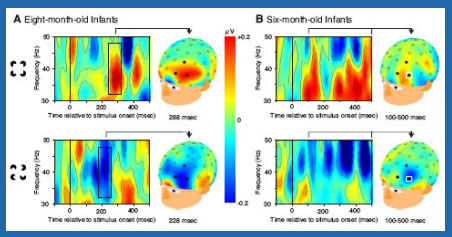
脑电图（EEG）



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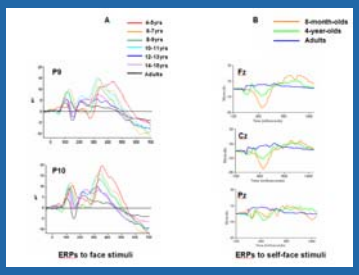
事件相关电位（ERP）

- 针对某个特定刺激做出反应的平均EEG



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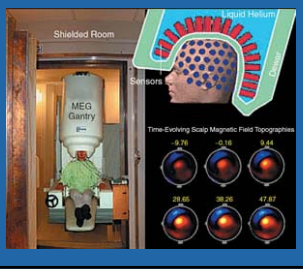
脑磁图（MEG）

- EEG的变体
- 记录神经电活动所产生的磁场，提供了更好的空间分辨率

只能探测沟，不能探测回
（由树突的排列方式所致）



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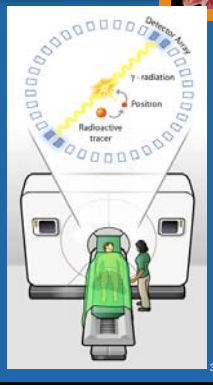
正电子发射断层扫描（PET）

- 将一种放射性示踪物质注射至人体的血流中，然后被试在PET设备中完成实验任务
- 大脑越活跃的区域新陈代谢消耗越大
- 通过探测正电子湮灭释放的成对光子，得到大脑不同区域的新陈代谢情况
- 空间分辨率较高
- 时间分辨率较低



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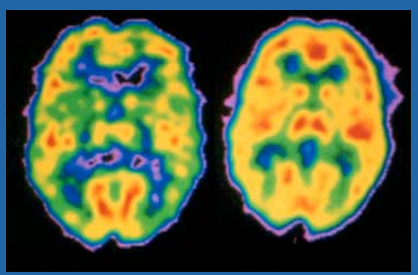

PET 扫描的精神分裂症患者（左）和正常人（右）的大脑

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MRI & fMRI

- 磁共振成像（MRI）——结构
- 功能性磁共振成像（fMRI）——功能
- 比PET更佳的空间分辨率，更低的倾入性
- 时间分辨率较低

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- 原理：神经活动越活跃的区域，氧合血红蛋白越多（身体对工作脑区的过度补偿）
- 机器发射的电磁波穿过大脑，使得血红蛋白中的铁产生局域磁场，该磁场可用安置在头部周围的磁传感器探测到

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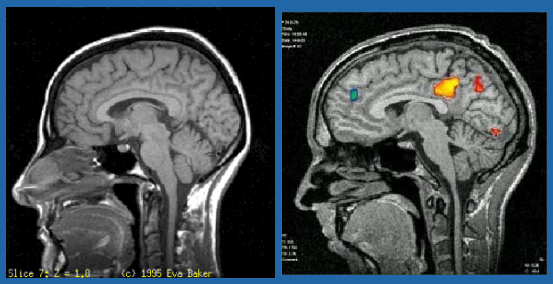

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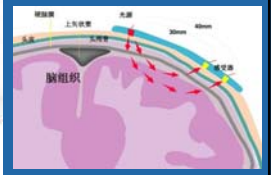
fNIRS



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方法	空间分辨率	时间分辨率	侵入度	费用（仪器购置费；使用费）
脑电 EEG ERP	差 （约1英寸）	优 （毫秒级）	低	低 低
脑磁 MEG	良好 （低于1厘米，但只能探测沟，不能探测回）	优 （毫秒级）	低	昂贵（需要特殊磁屏蔽房间） 中等（需定期维护以保持超导体处于极低温度下）
PET	良好 （约1厘米）	差 （每40秒产生一副图像）	高	昂贵（需要回旋加速器） 昂贵（每个被试约2000美元）
磁共振 (f)MRI	极优 （约0.5厘米）	取决于分辨率水平，通常几秒钟	低	昂贵（需要特殊的屏蔽房间） 中等（需定期维护）
近红外 fNIRS	目前较差 （约2厘米）	高 （最高可达数10Hz）	中等/低	低 低

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共同缺陷，在解释结果时需谨慎：

1. 无法辨别结果是由脑的兴奋还是抑制引起的
2. 更强的激活不一定意味着更多的加工
3. 同一功能在不同的脑中可能位于稍微不同的解剖区，导致在不同被试之间计算平均数据变得困难
4. 静息状态下脑也是活跃的，因此“测试”和“基线”下到底发生了哪些加工不清楚，二者的差异也很难解释
5. 如果一个大脑区域的激活在任务1-任务2中不显著，可能意味着该区域被同时激活，或者差异很小不足以被探测到
6. 不同的加工不一定需要不同的神经组织来执行。比如17区，加工颜色和形状的神经元混在一起

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因果性神经成像方法

- TMS
  - Transcranial magnetic stimulation 经颅磁刺激

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经颅磁刺激（TMS）

- 将一个线圈置于头部的特定位置并将磁脉冲传送到这个区域，使得线圈下的脑区的功能受到干扰
- video\TMS.mp4

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- 单脉冲；重复TMS（rTMS）
- 缺点：
  1. 刺激一个脑区产生的影响可能会扩散到其他脑区，这样就难以推断到底哪个脑区应该对观察到的效应负责
  2. 如果不按照安全指导使用，rTMS可能引发癫痫
  3. 只能影响大脑皮层，而且是那些直接位于颅骨下方的皮质部分
  4. 当TMS作用于额部时，前额两侧的肌肉会出现令人不适的抽动

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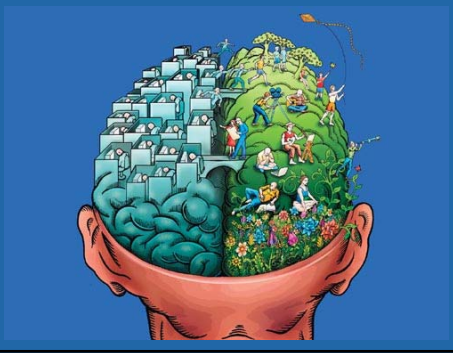
Tale of Two Hemispheres(补充)



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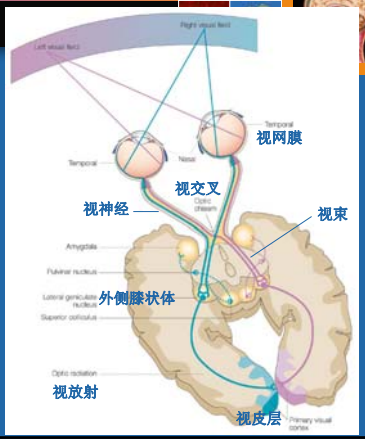
Anatomy of visual pathway



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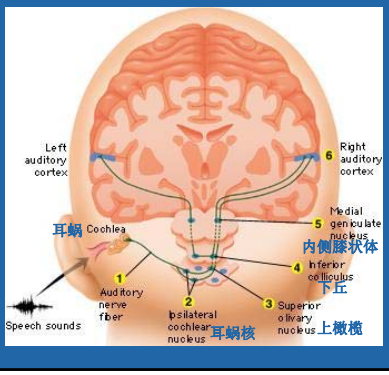
Anatomy of auditory pathway



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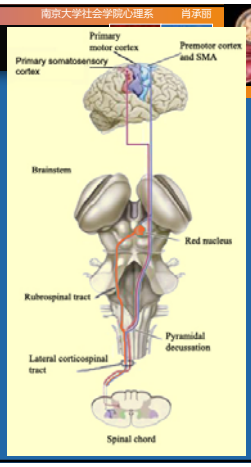
Somatosensory and motor pathway



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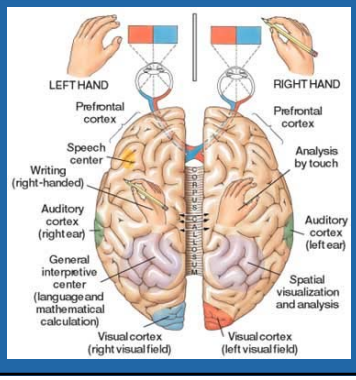
Contralaterality of the brain



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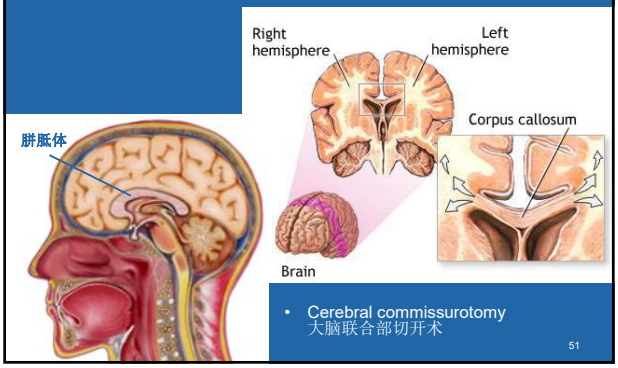
Corpus callosum



- Cerebral commissurotomy
  大脑联合部切开术

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- In 95% of right-handers, the left side of the brain is dominant for language.
- Even in 60-70% of left-handers, the left side of brain is used for language.

Broca's Area

Wernicke's Area

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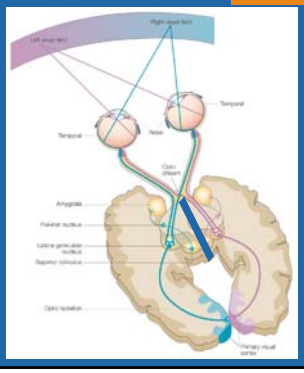
Cerebral commissurotomy

- To confine the effects of an epileptic seizure to one hemisphere



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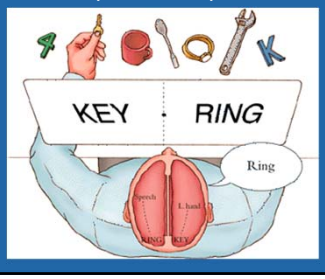
Split brain research

- Sperry & Gazzaniga
- Brief visual presentation
  - Only one hemisphere can process



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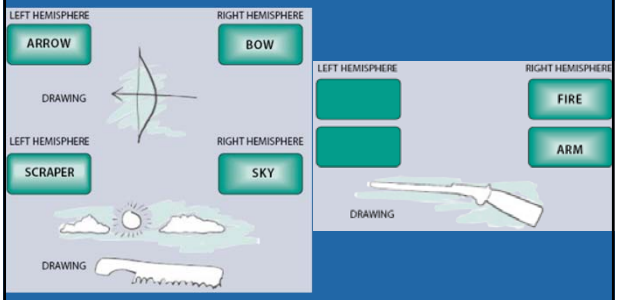
- The ability to synthesize information is lost
  - Gazzaniga, M. S. (1998)



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Chimeric faces – split brain patients

- Levy, Trevarthen, & Sperry (1972)
  - Verbally describe?
    - Man
  - Select from photographs?
    - Woman

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Cerebral functions

- Participants with intact corpus callosums

Research design
Participant variables
Failure to replicate

Left Hemisphere		Right Hemisphere
Sound related to language	Auditory system	Music, environmental sounds
Unknown	Spatial processes	Geometry, direction sense, mental rotation of geometric forms
Unknown	Somatosensory system	Tactile recognition, Braille盲文 detection
Verbal memory	Memory	Nonverbal memory
Speech, reading, writing, arithmetic	Language processing	Metered prosody 有节奏的韵律
Letters, words, surrealistic超现实主义 art	Visual system	Geometric patterns, faces, realistic art
Complex voluntary movement	Movement	Spatial-pattern movements

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- Evolutionary explanation (Corballis, 1989)
  - The evolution of hemisphere specialization may be associated with flexibility of thought思维灵活性 and generativity生成能力 or the ability to combine elements using rules to create new associations—be they words, sentences, or more complex tools
  - Fascinating, but should be considered in light of studies done on language processing and tool use by chimpanzees and apes

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Chimeric faces – participants with intact Corpus Callosums

- You are:
  - right-handed
  - left-handed
- You will see two pictures. Each picture is a combination of two photos that are split in half and put together. This is referred to as a 'chimeric' photo. Your task on each trial is to choose which chimeric photo looks younger. Press the i key to indicate that the top chimeric photo looks younger. Press the k key to indicate that the bottom chimeric photo looks younger. After making your choice, press the space bar for the next trial.

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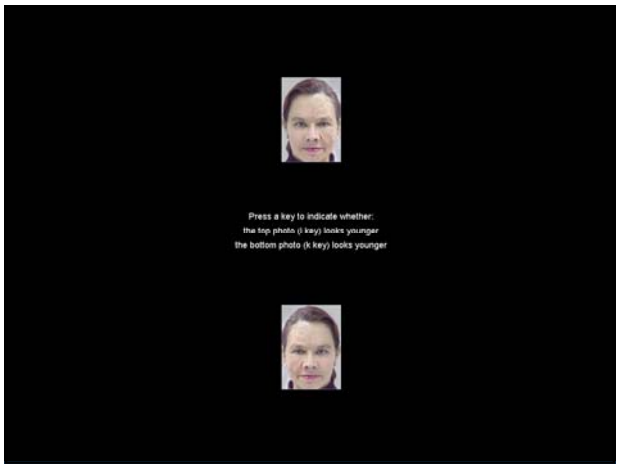

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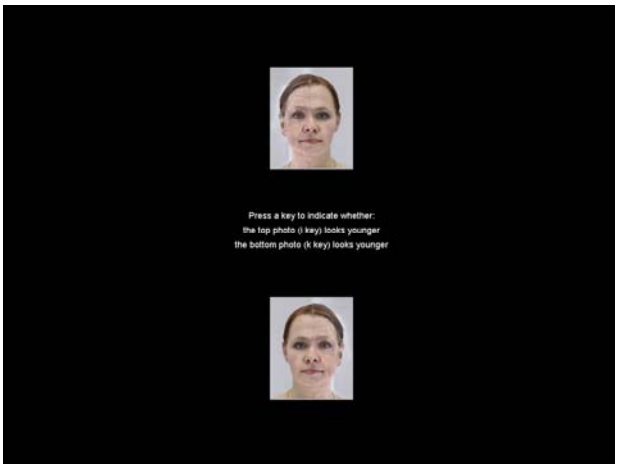

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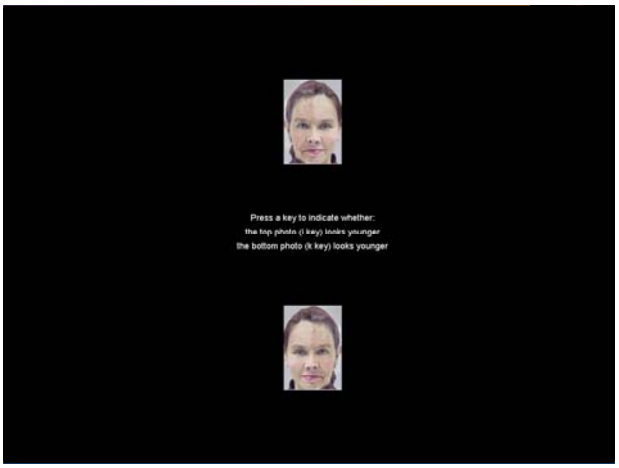

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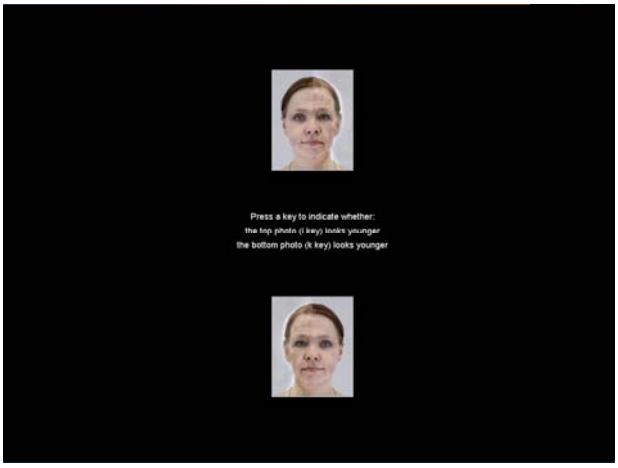

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What methods did we employ in this experiment?

- This experiment was based on a technique proposed by Rueckert (2005)
- On each trial, two chimeric faces were always mirror images of each other, so they had identical age information. Thus, just based on the characteristics of the images, we would expect no preference for one image over another.
- Independent variable
  - the construction of the chimeric faces. For one of the faces, the left side of the face was younger than the right side of the face. The opposite was true for the mirror image chimeric face.

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What do we predict participants will do? Why?

- Different behavior for right-handed and left-handed observers
  - Right-handed observer
    - the right hemisphere tends to be more strongly involved in judgments about faces than the left hemisphere
    - report that the chimeric face with the younger half on the left will look younger than the mirror image (with the younger half on the right)
  - Left-handed observer
    - do not show as strong differences between the left and right hemispheres
    - the percentage of reports that the chimeric face with the younger half on the left looked younger will be smaller for left-handed people than for right-handed people
  - This finding is an important control because it indicates that the bias among right handed subjects is not due to a general left-view bias (that might arise from living in a world in which reading goes from left to right).

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How robust is this effect? Are there limits to this effect?

- The difference between right-handed and left-handed people tends to be quite strong and exists for many different situations.
- However, an individual person may not show the effect. The lack of an effect for an individual may indicate that hemispheric differences are not very large, or that they judge faces differently than other people. There is natural variation across people.

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Readings

- Levy, J., Heller, W., Banich, M. T., & Burton, L. A. (1983). Asymmetry of perception in free viewing of chimeric faces. *Brain and Cognition*, 2, 404–419.
- Rueckert, L. (2005). A Web-Based Study of Cerebral Asymmetry for Perception of Emotion. *Behavior Research Methods*, **37**, 271-276.

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A holistic organ

- Even in the case of hemisphere specialization, the brain seems to operate as a holistic organ.
  - It should be noted that many of the research paradigms reported here involved patients whose corpora callosa had been severed and were designed to demonstrate the bilateral nature of the human brain.
  - In normal humans the connective tissues are intact, and the two hemispheres operate cooperatively with massive "communication" between them.

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Demonstration

- **The Squeeze Circuit**
  - Males and females (should have at least 15 of each), sit on the floor in a single file (males in one line, females in the other).
  - A stopwatch, record the time required to complete the circuit.
  - The procedure may be repeated to improve efficiency and time.
  - everyone close your eyes

1. with your right hands on the right shoulder of the student in front of you; the first person in the line is cued to squeeze the shoulder of the person they are facing. As soon as a person feels the squeeze, they are to squeeze the shoulder of the person in front of them, passing on the squeeze signal, like neural signals in the body.
2. Next, turn shoulder-to-shoulder and place your right hands on your neighbor's ankle. Repeat the signal transmission and compare the times required to complete the circuit.

  - Compare differences within gender group trials and between groups

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- Insights:
  - This is actually an example of a quasi-experiment, since gender is a quasi-experimental variable (subjects cannot be randomly assigned to either condition). Cause is difficult to surmise in quasi-experimental designs due to the fact that subjects are not randomly assigned to groups, opening up the possibility that factors other than the manipulated ones may be correlated with the experimental groups.
  - In this example, for instance, there may be aspects of being male or female other than biology that affect the subjects' performance here. While comparing within group inter-trial differences, you should find that transferring the signal using ankle-to-hand transmission requires more time to complete. This is an indicator of the increase in time required for neural transmissions from the ankle to the head, compared to shoulder to the head. To calculate an estimate of the speed of sensory neural transmission, divide the increase in elapsed time by the number of students, and then divide this figure by the average of the distance from the ankle to the shoulder (around 0.9 or 1.2 meters).

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