Brain

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The study of how the brain enables cognition is a relatively recent enterprise.

- Recent advances in neuroimaging techniques provide a more comprehensible view of the inner workings of the brain when people are performing cognitive tasks.
- Ongoing challenge now is to develop new experimental paradigms that can conclusively link cognitive processes to underlying neural activity
- Resulted in more psychologists are interested in the brain as an underpinning of cognitive activity
- The maximum brain weight of 1350 grams is achieved when the individual is about 20 years old.

One can make the analogy that the mind is to the brain as software is to a computer.
Bryan Kolb

- First to show ho the growth of new brain cells following injury can restore cognitive and behavioral function.
- Lead to the development of new treatments and strategies for improving behavior following the early brain injury, and offers new insights into recovery of function in victims of stroke, Alzheimer's disease and drug abuse.

Structure of the brain

- Forebrain: the cognition happens
- Midbrain & hindbrain: regions are mainly responsible for lower level, non-cognitive functions
  - hindbrain develops one of three bulges in the embryo's neural tube.
  - Structures within the hindbrain are the most primitive
  - Three major structures:
    * Medulla oblongata: transmit information from the spinal cord to the brain and regulates life support functions (respiration, blood pressure, coughing, sneezing, vomiting, and heart rate)
    * Pons: acts as a neural relay center, facilitating the "crossover" of information between the left side of the body and the right side of the brain
    * Cerebellum(小脑): contains neurons that coordinate muscular activity;
      · one of most primary brain structures.
      · Govern balance (general motor behavior and coordination)
      · lesions in the cerebellum cause irregular and jerky(不平衡) movements, tremors and impairment of balance and of gait(步态)
  - midbrain: in the middle of the brain
    * involved in relaying information between other brain regions
    * keep us awake and alert
    * involved in sudden arousal need to respond to a threatening or attention-grabbing stimulus

Forebrain

Break into two sub-sections:

- Subcortical Structures
  - Sub-cortical regions are those regions of the brain that sit beneath or under the cerebral cortex.
  - Thalamus(丘脑):

        * center of the brain
        * relaying information especially to cerebral cortex
        * switching or relaying for sensory information across different sensory modalities, which are represented in different areas of the brain.
        * information get received and processed by multiple regions of the brain can be come integrated and can cross-modaly communicate with each other via thalamus
    - Hypothalamus(下丘脑):
        * controls the pituitary gland by releasing hormones
        * Regulates basic biological functions(homeostatic behaviours) including hunger, thirst, temperature, sexual arousal and basic emotional reaction
    - Hippocampus(海马体):
        * formation of long-term memories
        * Critical structure for learning, memory and emotion
        * break it $\rightarrow$ cannot have the ability to consciously recollect personal events
    - Amygdala(杏仁体):
        * Supporting cognitive process
        * Involved in memory, emotion and aggression; specifically the emotional content of memories (emotion learning)
        * Modulate(调整) the strength of memories in terms of its emotional content
- Cortical Structures
    - The white matter connects the cerebral cortex(大脑皮层) to the sub-cortical regions of the brain
    - Central sulcus: divides the frontal and parietal lobes
    - Lateral sulcus define the temporal lobe
    - Cerebral cortex(大脑皮层) can be divided into four main lobes
        * Frontal lobe (大脑额叶)
            · Motor cortex: directs fine motor movement

· Premotor cortex: involved in planning such movements

· Prefrontal cortex(前额皮质):

- support wide range of cognitive functions; involve with executive function (involves planning, making decisions, implementing strategies, inhibiting inappropriate behaviours, using working memory to process information)

- Damage → changes in personality, mood, affect and ability to control inappropriate behaviour;

- longest period of maturation (last brain regions to mature); first-to-go in aging effects

* Parietal lobe (顶叶)

· contain the somatosensory cortex: contained in the postcentral gyrus

· Support cognitive functions(spatial processing and attention)

· Somatic sensory cortex: Sensing information from the body (pain, pressure, touch or temperature)

* Occipital lobe (枕叶)

· Processing visual information (like visual stimuli, such as orientation, shape & color) and also (recognizing what objects are)

* Temporal lobe (颞叶)

· Processing auditory information

· Supporting functions associated with the encoding and the retrieval of information from long-term memory

· Damage it can also result in memory disruption

– No connections between two lobes in the cortex, but information between two cerebral hemispheres of the brain can be communicated via the corpus callosum and anterior commissure(前连合)

– Brain region with most plasticity over the longest periods → most sensitive to environmental toxins or stressors.

Localization and Lateralization of Function

- Franz Gall:
  - Faculty Psychology
    - Certain human abilities and traits(human nature, conscientiousness, constructiveness) were associated with **specific** regions of the brain. Each of these abilities and traits(特征) were **autonomous and independent**
    - ability in one domain will not impact ability in another domain.
  - Johan Spurzheim:
    - Argued that the strengths and weaknesses of specific traits and abilities were precisely correlated to the relative sizes of the different brain regions.
    - Thus **Phrenology** is born
- Phrenology(骨相学)
  - Larger region → better performance in certain area
  - Two assumptions:
    - The size of a portion of the brain corresponded to tis relative power
    - Different faculties are absolutely independent
  - Reason to discredit:
    - The overall size of a brain or brain area is not indicative of the functioning of that area → different configuration of bumps and indentations in a brain does not determine or even predict how an individual will function cognitively or socially
    - Many cognitive processes are to some degree in the brain
    - The assumption that these processes completely autonomous and independent.
    - The cognitive processes operate highly interactively instead of vacuum. The portion of the brain does not directly correspond to its relative power.
- Double Dissociations

  - Brain damage to area X → impaired by cognition A, but not B.
  - Brain damage to area Y → impaired by cognition B, but not A.
  - When brain damage and behaviour are completely dissociated from each other and show opposite mirror image patterns.
    e.g. Broca's (left frontal lobe) and Wernicke's (left(superior posterior) temporal lobe) Aphasia
    Damage in Broca's area: patient will have a major deficit in expressive language or speech production.
    Damage in Wernicke's area: patient will show deficits in the comprehension of language, but intact speech production.

- Mapping between specific locations within primary motor cortex
  - Primary somatosensory cortex(parietal lobe behind the motor cortex)
    * each part of it receives information from a specific part of the body
    * the total amount of "brain real estate" devoted to a particular part of the body is **not** the size of the body part.
  - Establish connections between lesions in other parts of the brain and specific cognitive functions.
  - Researchers found: select regions to specific portions of the primary motor cortex would result in the loss of a specific motor control of a select body part.

- Wilder Penfield
  - Developed a ground breaking procedure – "Montreal Procedure" → to local anaesthetic(麻醉) and guided by the responses of the patient
  - Patients are only local anaesthetic and were conscious enough to talk to him, then he probed(探索) the exposed(暴露) brain tissue guided by the responses of the patient. (search for the scar(伤痕) tissue that caused the epilepsy(癫痫))
  - Clearly mapped out the specific functions performed by various regions of the brain based on participant's responses to the cortical stimulation (created a map of the sensory and motor cortices of the brain(大脑皮层运动反应区))

- Karl Lashley

  - Study the effect of brain ablation(脑毁损) one the maze-running ability of rats
  - reported: maze-running was related to the total amount of cortex removed → brain is dynamic
  - some more complex cognitive functions likely rely on a combination of regions

- Black & Kolb
  - complicating involved picture of brain organization is the notion of the plasticity of the brain
  - some brain region can take over functions of damaged regions
  - the younger the patient and the less extensive the injury, the better is the chance of regaining function

- Lateralization
  - Two cerebral hemispheres play different roles when comes to cognitive function (language)
  - **specialization for language:** left hemisphere be larger in size (in the area where language is localized)
  - **Bilateralized:** having language function in both hemispheres
  - If left hemisphere for language,
    * left hemisphere as the analytical one and right hemisphere as the synthetic(综合) one
    * Left: good at processing information serially
    * Right: put individual elements together to make up a whole
    * right hemisphere has larger parietal and temporal area; lead to better integration of visual and auditory information
    * right hemisphere also working on geometric puzzles, navigation, musical ability
  - The vast majority of individuals have two quite functional cerebral hemispheres that continually interact to process information and carry out cognitive functions
  - Only one hemisphere would be active in everyday tasks are remote

  - Corpus Callosum: sends information from one hemisphere to the other very quickly

Brain Imaging Techniques

Non-invasive procedures:

- static imaging – the structure of the brain
- dynamic brain imaging – the function of the brain

Structural neural imaging techniques

- CAT(computerized axial tomography) scan
  - Focused converging beams(光波) of X-rays from different angles
  - Allowing visualization of the organ – **differing densities**
  - Shows 9 to 12 different "slices"
  - pinpoint areas of brain damage and make inferences about the relative "age" of the injury
- EEG (Electroencephalography)
  - detect different states of consciousness
  - The waveforms record changes in predictable ways
  - provide the clinician or researcher with a continuous measure of brain activity
- MEG (Magnetoencephalography)
  - Measure changes in magnetic fields generated by electrical activities of neurons
  - Gives more precise localization of brain region activity than EEG
- MRI(Magnetic resonance imaging) scan
  - take advantages of **different magnetic properties** of tissues in the brain
  - Under a powerful magnetic field, produce an electromagnetic signal → allow the visualization of the structure of the brain
  - People not good for MRI: pacemakers, people with claustrophobia,

- MRI Scan are preferred over CAT scans
  - MRI requires no exposure to radiation
  - More detailed image of underlying structures of the brain
  - Powerful functions: Measure the dynamic or functional aspects of the brain
- Provide static pictures of brain structure: → pinpoint brain damage and other abnormalities.
- Cannot show how functioning brain is working

Functional neuroimaging

- Measure electrical activity as a function of cognitive tasks
  - ERP (Event-related potentials)
  - Neurons fire in the brain → electrical activity.
  - Placing metal electrodes on the scalp (头皮) → measure the electrical activity
  - Measure an area of the brain's response to a specific event
  - Measure the time course, source/location of activities → how brain is responding to certain cognitive stimuli.
- Measure byproduct of electrical activity
  - Byproduct of neuroactivity is metabolism or blood flow in the brain
  - Methods: Positron Emission Tomography (PET), functional Magnetic resonance imaging (fMRI) → the most popular technique
  - PET rely on the fact that when an area of the brain is active more blood flows to it

fMRI – Measure the blood oxygenation level

- Measure the inflow and outflow of oxygenated blood in the brain by measuring the magnetic properties of that blood.
- oxygenated and de-oxygenated blood has different magnetic properties.

BOLD Function

- Inflow and outflow of oxygenated and de-oxygenated blood → blood oxygenation level dependent functions
- As neurons fire in the brain, blood flow increases as a function of neural activity in the brain → slow process
  - Interaction of the X and Y axis → started performing a cognitive task
  - 1. Brain that are responsible for that task consume oxygen → dip in the BOLD function
  - 2. A slow influx of blood to that region → to peak at 10 to 15 seconds
  - 3. fMRI picks up this BOLD function
- Researcher find regions of the brain that show BOLD function that is time-locked to the cognitive task — those regions relate to or are correlated with performance on that task.
- Disadvantage:
  - Difficult to know what regions of the brain are specifically responsible for what aspects of that task
    - Every cognitive task has plenty of underlying mechanisms that support that task

Donder's Subtractive Logic

- Originated with studies of reaction time differences
- Measure the time for a process to occur – compare two reaction times: one which has the same components as the other, plus the process of interest.
- Enable researchers to subtract out the background brain activity that is not related to the cognitive task of interest so they can see what brain areas are uniquely implicated in that task
- Applied to the analysis of functional neural imaging data

  - allows for the isolation of the regions of the brain contributing to a given underlying cognitive process
  - the relative amount of activation in a particular brain region can be measured by subtracting a control state

Example:
Color decision making – choose the color that you are interested in and push the button.

- Different components to that decision task, but the key process is the decision time.
- But there are additional components, manual component(bush button also takes time), for example.
- Want: decision-making time independent of the motor component of that task
- Applying subtractive logic:
  - Ask participants to perform a simpler task (push button without decision making)
  - Subtract their responses to the simpler tasks from the responses to the more complex task → we get pure measure of decision time independent of any sort of motor response

Summary

- CAT and MEI yield neuroanatomical information
- PET, SPECT and fMRI provide dynamic information about how blood flows during various cognitive activities
- MEG, EEG and ERP all measure electrical activity during cognitive activities