Neuroimaging

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Neuroscience

- Neuroscience is the study of human nervous system.

  «How the nervous system works?»

- The large majority of neuroscientist focus their research on the brain.

Neuroscience

- Three main goals of neuroscience:

  1. Understand the human brain and its function
  2. Understand how the nervous system develops and maintains itself.
  3. Understand neurological and psychiatric disorder and discover methods to diagnose and cure them.

  Neuroscience is an interdisciplinary science.

  A lot of disciplines including psychology, medicine, linguistics, chemistry, philosophy, engineering, biology, math and computer science etc. work together in neuroscience.

Functional Neuroimaging

- Functional neuroimaging is the use of neuroimaging technology to measure **brain function**
  - It discovers how brain works to execute a certain function and which brain areas responsible for a function.
  - Neuroimaging methods could be invasive or noninvasive
  - They could have good temporal or spatial resolution. Often there is a trade off between temporal and spatial resolution.
  - All techniques have limitations. There is no perfect method to investigate brain activity.

Functional Neuroimaging

- Some of the functional neuroimaging techniques:
  - (Lesion studies)
  - Direct cortical stimulation
  - TMS (Transcranial Magnetic Stimulation)
  - PET (Positron Emission Tomography)
  - EEG (Electroencephalography)
  - fNIRS (Functional near-infrared spectroscopy)
  - fMRI (Functional Magnetic Resonance Imaging)

Lesion Studies

- A lesion is the damage of a part of the brain that results in destruction of neurons in that part.
- Lesion methods are used in research as a means of seeing which parts of the brain are responsible for specific functions.
- Researcher conclude a specific function for a brain region according to the behavioral changes after the region got damaged.
- Lesions can come from natural sources (like brain injuries) but can also be deliberately caused for research (in animals).

Direct Cortical Stimulation

- Invasive procedure
- It is used during the open brain surgeries
- This method aims to localize the function of specific brain regions through direct electrical stimulation of the cerebral cortex
- Weak (1-10 mV) and high frequency (50 Hz) electrical current depolarize the brain region.
- It could produce positive or negative responds.
- It could trigger a seizure

TMS

- A simple coil placed on the head generate magnetic field and this is used to change activation of a small area of the brain.
- Less invasive method
- It cause a fake and temporary lesion.
- Researchers observe behavioral changes of patient

- For example, after applying TMS to prefrontal cortex, participants could not do attention tasks. Therefore we could suggest that PFC is related with attention.

fNIRS

- A non-invasive, safe, and low-cost method
- In fNIRS, near-infrared light is projected through the scalp and the skull into the brain and the intensity of the light that is refracted is recorded.
- Neural activation in response to a stimulus results in increased blood flow to the area increased.
- The blood flow, changed absorbtion of the light, therefore light intensity.
- Changes in light intensity is recorded and it is used as a representation of a activity in brain.

PET

- Observe metabolic changes in body
- A metabolic substance that labeled with a radioactive isotope (tracer) inject into body
- The tracer emits gamma rays that can be detected by the PET scanner.

- For brain imaging, radioactively labeled glucose is used to detect active brain area (Active brain area draw more glucose from body).
- Because of the PET scanner detect the labeled glucose, it can detect the active area

fMRI

- fMRI measure brain activity by detecting changes associated with blood flow
- MRI uses magnetic field and radiofrequency to create image There is no ionizing radiation that consists X-ray or gamma ray.
- It is a non-invasive and safe imaging method for clinical use and neuroscience.

fMRI

- Magnetic density measured in Tesla (T)
- Most MRI machine performed at 1.5T, 3T or 7T (Magnetic field of fridge magnets 0.005T; magnetic field of earth 0.00003T)
- Magnetic field created by coils.

MRI

- Protons are spinning around their own axis. It calls nuclear spins.
- Normally directions of their spin random but they align when there is an external magnetic field. Just like iron dust align with the magnetic field of a magnet.
- They continue their spin while they align with the magnetic field.

MRI

- Human body is composed of 70% H_2O
- Hydrogen is the most common element in tissue
- MR imaging relies on the magnetic properties of H^+ ion.
- Spining axis of proton align with the magnetic field of MRI when patient lie down in the scanner

MRI

- Radiofreqency coils transmit radiofrequency (RF) pulse.
- RF pulse create a disturbance with alignment of proton.
- Before the RF pulse spinning axis of protons are align with the magnetic field. After the pulse spinning axis change.
- Protons absorb the energy from RF pulse and flip to a high energy state

MRI

- After RF pulse removed, protons seek to return their equilibrium state (they align with the external magnetic field again)
- While they are returning back their align stage they transmit the energy which they absorbed

fMRI

- The signal that proton transmit while they are returning back to normal state differs from different tissue.
- For example cerebrospinal fluid is different than gray matter
- This difference is responsible to create different images.

fMRI

- Functional MRI works with same physical principles with MRI.
- However, fMRI can detect neuronal activity indirectly through changes in blood flow.
- How fMRI can do that?

Physiology of fMRI

- Cells of human body need energy to function.
- Cellular respiration is a chemical reaction that happens in all living cells and it is the way that create energy for cell itself.
- Glucose and oxygen react together in the cells and produce carbondioxide, water and energy.
- To create energy, human cells need oxygen and glucose.
- These ingredients are carried around in the bloodstream.

Physiology of fMRI

- Oxygen is carried in the blood with molecule called hemoglobin in red blood cells.
  - Oxygen loaded (oxygenated) hemoglobin called oxyhemoglobin.
  - The form of hemoglobin without oxygen is called deoxyhemoglobin.

- Oxyhemoglobin is diamagnetic (does not affected by magnetic field)
- Deoxyhemoglobin is paramagnetic (it become magnetized in a magnetic field)

➢ *Deoxyhemoglobin distrupt magnetic field.*

Physiology of fMRI

- When neurons process information their metabolical demands increase.
- Processing information happens due to electrical and synaptic changes in neurons.
  - Electrical changes in the neuron (action potential, postsinaptic potential etc) change ion gradient of neuron.
  - Synaptic processes change neurotransmitter levels
- Neurons need energy to restore these changes
  - Blood flow carry oxygen and glucose to the neurons

Physiology of fMRI

- Cerebral circulation is the most important circulation in the body.
- Arrest of cerebral circulation for more than few seconds causes loss of consciousness. Arrest for more than few minutes causes irreversible damage of the brain.
- Brain has high metabolic rate:
  - It accounts for 2% of body weight (1.2-1.5 kg). However, it responsible 20% of our oxygen consumption.
  - It receives 750 ml blood/min

Physiology of fMRI

- When a person run, blood flow to legs get increased because of the need of oxygen and glucose. Blood vessels dilate and blood flow increase in order to restore metabolic ingredients.

- Just like other parts of the body activation of a brain region cause great metabolic demand. Working brain area needs more oxygen and glucose than the other areas. Therefore blood flow increase.

Physiology of fMRI

- Deoxyhemoglobin is paramagnetic and it changes magnetic field.
- If deoxyhemoglobin increased MR signal weaken; if deoxyhemoglobin decreased MR signal gets stronger.
- When one brain region activated it uses oxygen from hemoglobin and dexoyhemoglobin increase.
- After this momentary change blood flow to active area increased.
- *Not just to oxygen demand is met, but more blood than brain region need flow to the area.*

➢ Blood oxygenation increase and deoxyhemoglobin level decrease.

fMRI

1. Brain region use oxygen and deoxyhemoglobin level increased.
2. After that there is lot more blood than needed come to this region.
3. New blood is oxygenetad therefore, deoxyhemoglobin level decrease in that area.

BOLD

- Decrease of deoxyhemoglobin means more strong MRI signal.
- Therefore active brain area means stronger MRI signal.
- This signal is related to blood oxygenation.
- Blood oxygenation level dependent signal= BOLD signal

- BOLD signal peaks 4-6 seconds after the neuronal activation

fMRI

- Temporal resolution of fMRI relatively weak (a few seconds).
- Lots of neuronal change could happen during the few seconds and fMRI cannot detect this changes.
- Spatial resolution is good. fMRI can detect changes in all of the brain in millimeter level.

fMRI Studies

For investigating a cognitive process:

1. Developing a task
2. Image Acquisation (fMRI Scanning)
   - Safety
   - Preparing the scanner
   - Scanning and collecting data
3. Image Analysis

fMRI Tasks

Developing a Task

- Most important stage of a neuroscience study
- Developing a task that related to the brain function which you would like the examine

Few examples;

- Stroop task (inhibition)
- N-back task (memory)
- Oddball task (attention)
- Facial expression tasks (emotion)
- Spatial perception tasks

fMRI Scanning

Safety

- There is no short-term or long-term damage of fMRI.
- However it is a powerful magnet and it could be dangerous closing to scanner with metals.
  - Metals could be attracted by magnet in the scanner
  - Metals could be heated due to magnetic field.
  - Metals interfere with the image, it could ruin the data.

fMRI Scanning

Preparing the scanner

- Visual system
  - Participants can see the task while they are lying down inside the scanner
- Sound system
  - It allows us talk to the participants
- MRI compatible buttons
  - Participants can give their answer to the task inside the scanner

➢ They can see and answer the task

fMRI

Image Analysis

- High capacity computers (work station) are required for analyzing fMRI data
- After the analyze we can see the active brain region while the participant doing the task we gave them

THANK YOU