Neuroscience Notes

Contents

Studying the Human Brain & amp; Electrophysiology in Humans

1 How do we image human brain?

1. Structural imaging
    - Computerized tomography (CT)
    - Magnetic resonance imaging (MRI)
2. Functional imaging
    - Positron emission tomography (PET)
    - Functional MRI (fMRI)

1.1 CT Scanning

- Different types of tissue have different levels of x-ray absorption.
- CT creates images based off this.
- Developed in early 1970s.
- Non-invasive.

1.2 Magnetic Resonance Imaging (MRI)

- Utilizes magnetic properties of **atomic nuclei**.
- MRI switches brain from a low to high energy state.
- Calms back down in between scans, then evaluate differences in images.
- In biopsychology, we would specifically measure **hydrogen atoms** in both water and fat of the brain.
- Non-invasive.

1.2.1 Advantages of MRI over CT

- No required exposure to radiation
- MRI images have better resolution.

1.3 Positron Emission Tomography

- Utilizes a **radioactive 'tracer'**.
- Example: tracer attaches to oxygen ¿ locates water in the brain, OR tracer attaches to fluoride ¿ locates glucose in the brain.
- Specifically in neuroscience, the radioactive **2-deoxyglucose (2-DG)** is used as a tracer

  Mimics glucose (brain's energy source) in the brain.

  Accumulates in neurons and glial cells as opposed to metabolizing.

  Differing levels of 2-DG throughout the brain reflect amount of activity in different regions.

  + If you start out your scan, whatever task it is that you want to look at, you see that this one area of the brain has a much higher concentration of two deoxyglucose than another area of the brain, especially in comparison to like a resting scan. Then it would be safe to assume in this case that, that place where there is more of an accumulation of glucose, it's requiring more energy.
  + If it's requiring more energy, that part of the brain is probabily important for whatever task that person is undergoing.

1.4 fMRI

- Measures concentration of **deoxyhemoglobin** in the blood of the brain.

  Dealing with oxygen.
- As a region becomes more active, it requires higher levels of oxygenation.
- **BOLD response**: blood oxygen level dependent contrast.
- Disadvantage: Poor temporal resolution, images take 2-3 seconds to develop following brain activity itself.
- Relationship between BOLD and neural activity still unclear.
- Non-invasive

1.4.1 Advantages of fMRI over PET

- No radioactive injections
- Both structural and functional
- Better spatial resolution
- Produces 3D images

1.5 Transcranial Magnetic Stimulation (TMS)

- Only method for non-invasively stimulating the brain.
- Used to alter activity within the cerebral cortex
- Large coil that creates a magnetic field is places near the skull
- Brief or prolonged stimulation from coil can either change or stop the activity of different brain regions
- Behavior before and after stimulation is observed

2 Psychophysiological Recording in Humans

Psychophysiological techniques:

- Electroencephalography (EEG)
- Electromyography (EMG)
- Electrooculography (EOG)
- Skin Conductance Response (SCR)
- Cardiovascular Activity

2.1 Electroencephalography (EEG)

- Measures **electrical activity** of the brain.

  Action potentials

  Postsynaptic potentials

  Electrical signals from the skin, muscles, blood, and eyes

  Can only record signals from the cortex

  Similar to the TMS, of where you're saying specifically in the brain activity, not going to see responses and potentials deep into the brain.

  Not super worried about getting into any deep structures, only worry about looking at cortical activity.

  If we want to get into studying more of those subcortical structures, then we're going to use different methods like fMRI or PET.

- The procedure:

  Attach electrodes to scalp directly or with an **electrode cap**

  Record activity of neuron population under electrodes

  Spontaneous activity OR **event-related potentials** following a stimulus

2.1.1 EEG continued

- Waveforms on EEG outputs are called **electroencephalograms**.

  Some correlate with different states of concsciousness or pathologies.

  For example, epileptic seizures have distinct EEG waveforms.

- Downfall is we can only go pretty shallowly into the cortex, cannot go much deeper than that.

2.1.2 EEG continued

- High temporal resolution, but poor spatial resolution.
- Newer methods of EEG allow representation of signals by 3D MRI images, improving localization.

2.2 Electromyography (EMG)

- Records muscle tension

  Contractions of the muscle fibers that comprise skeletal muscle.

  We have different kinds of fibers inside our muscles that are associated with different receptors and perceivable of different signals through different nerves or locations of the brain or from the environment vs our brain.

  Using EMG to have a good representation of whatever what we want to study.

- Procedure:

  Two electrodes are taped over muscle of interest.

  Raw signal: number of muscle fibers contracting at any given time.

  Integrated signal: simpler measure of muscle tension.

2.3 Electrooculography (EOG)

- Records changes in electrical charge following eye movement.
- Electrodes are place above and below eyes (vertical movement) or to the left and right of the eyes (horizontal movements)

  Use this for eye tracking things.

  Present different stimulus, want to evaluate exactly how somebody is visually processing that stimulus, then using EOG.

2.4 Skin Conductance Response (SCR)

- Emotional experiences can be reflected by increases in **skin conductance** (ability of skin to conduct electricity).
- **SCR**: measures changes in skin conductance in response to specific events or experiences.

  Likely due to **sweat gland activity**

- Procedure:

  Sensors are placed on an area of the skin with a high number of sweat glands, like the fingers.

  This is partially how **polygraphs** are conducted.

2.5 Cardiovascular Activity

- **Cardiovascular system:** blood vessels and heart

  Activity can change depending on **emotions**.

- Most used measures:

  Blood pressure

  Blood volume

  Heart rate

- Heart rate is measured using an **electrocardiogram (ECG)**
- Measures electrical activity of the heart using electrodes placed on the chest.
- Compare heart rate before and after a specific stimulus.

Invasive Techniques in Animals

Write an overview of the topic here.

3 What kinds of invasive measurements are there?

1. Electrical stimulation
2. Electrophysiological recording
3. Lesions

   Requires **stereotaxic surgery**

4. Genetic techniques

3.1 Stereotaxic Surgery

- Vital step that comes before most invasive recording or stimulating methods.
- Allows for the placement of experimental devices...

  Electrodes

  Small knife blades

  Cryoprobes

3.1.1 How is stereotaxic surgery performed?

- An atlas of the brain (or **stereotaxic atlas**) is used to locate the structure of interest.
- Animal is then anesthetized and placed into the **stereotaxic instrument**.
- A hole is then drilled through the skull, and the chosen device is inserted.

4 Electrical Stimulation

- Induction of increased neuronal firing via a current passed through an electrode.
- This allows us to gather information about the function of a particular brain area.
- Through electrical stimulation, we can alter behaviors such as...

  Eating

  Drinking

  Aggression

  Copulation

  Sleeping

4.1 Recording Methods

1. **Intracellular unit recordings:** insertion of microelectrode *inside the cell membrane of a neuron.*
2. **Extracellular unit recordings:** insertion of microelectrode into the extracellular fluid.
3. **Multiple unit recordings:** electrode picks up signals from multiple neurons (units).
4. **Invasive EEG:** large electrodes pick up field of electrical activity within a chosen region.

5 Lesioning

- **Lesion:** to remove or damage an area of the brain.
- Observe behavior before and after lesion and compare to non-lesioned controls.
- Can be **unilateral** or **bilateral** (i.e., only the left hippocampus or both hippocampi, respectively).
- Issues associated with lesioning...

  Bordering tissue is likely damaged as well.

  The above can be a confounding variable, i.e, observed effects might be from the lesioned bordering tissue rather than the targeted tissue.

- There are four types of lesions...
    1. **Aspiration**: a fine-tipped glass pipette is used to suction out a portion of the cortex.
    2. **Radio frequency**: a high frequency electrical current that produces heat that destroys neurons.
    3. **Knife cuts:** a blade or scalpel is used to sever a part of the brain.
    4. **Cryogenic blockade:** coolant pumped through a cryoprobe "freezes" or causes a neuron to stop firing.

        This is reversible; once the neurons warms back up, they can fire again.

6 Genetic Techniques

- **Genetic knockouts**: delete a gene of interest.
- **Genetic knockins**: overexpress a gene of interest.
- **Transgenic lines** (primarily mice): insertion of a gene from another species, or specific editing of the genome for the expression of certain traits.

Testing Animal Behavior

Write an overview of the topic here.

7 Behavioral Testing in Mice and Rats

One way we can study cognition is through behavioral tasks. In mice and rats, one of the most common ways to do this is through different types of mazes.

7.1 1. Morris Water Maze

- Tests spatial learning through visual cues (typically on the walls) and a platform the animal must swim to.
- Water controls for extraneous variables since rodents don't like having to swim.

7.2 2. Barnes Maze

- Similar to the MWM, the Barnes maze also tests spatial navigation and memory.
- Target hole (usually with a treat) and visual cues around the room.

7.3 3. Y-Maze

- Tests short-term memory, as well as exploratory behavior in mice and rats.

7.4 4. Elevated Plus Maze

- Offers a great way to study anxiety and defensiveness in rodents.
- Mice and rats don't like open spaces and bright lights, the closed arms are preferred.
- Administration of drugs, treatments, etc. might change this.

7.5 5. Radial Arm Maze

- Another test for spatial learning and memory.

8 References

Include all references used here in standard citation format.