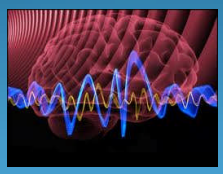
Introduction to EEG!



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ECR EEG Workshop
June 25 2013
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Overview

- What is EEG?
- Why use EEG?
- EEG equipment and supplies
- Collecting EEG data
- Common problems

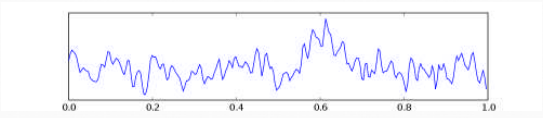
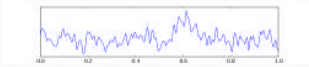


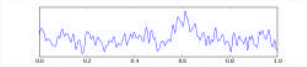
Image source: ANT Neuro website, www.ant-neuro.com

What is EEG?

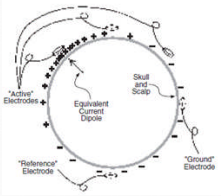


- **Electroencephalography**: measurement of electrical activity in the brain
- **Electricity** is the flow of a charge through a conductive medium
- In the brain, tiny **electrical potentials** are generated by the movement of charged particles (ions) across cell membranes
- EEG picks up the activity of clusters of neurons firing at the same time and in the same direction

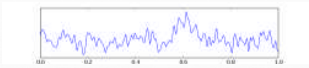
What is EEG?



- The *difference* in **voltage** (potential) between two sites: active electrodes and reference
- EEG potentials are summed activity of large populations of neurons
- Signals diffuse over distance
- EEG is biased toward activity of the areas closest to the electrode site (cortex)

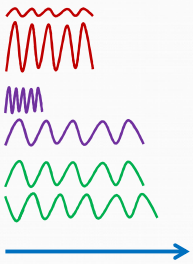


What is EEG?



Signals can be described in terms of:

- **Amplitude** (μV)
  - Magnitude/power
- **Frequency** (Hz)
  - Cycles (wave periods) per second
- **Phase**
- **Time/latency** (ms)



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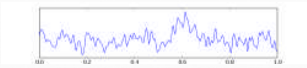
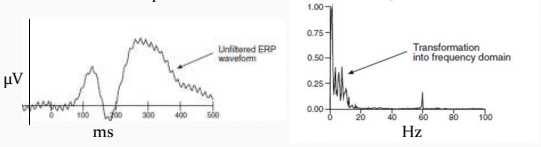


Fast-Fourier Transform (FFT)

Time and amplitude

Frequency and power



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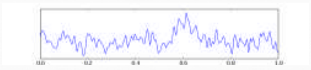
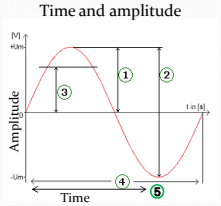


Time and amplitude



1 = Peak amplitude
2 = Peak-to-peak amplitude
3 = Mean/RMS amplitude
4 = Wave period
5 = Peak latency

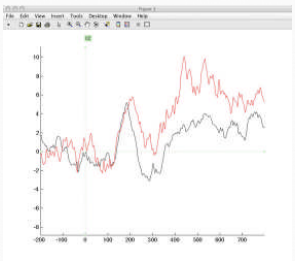
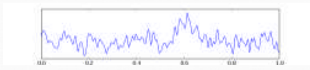


Image source: ERPLAB website, http://erpinfo.org/erplab

What is EEG?



- Rhythmic and transient activity
  - **Rhythmic**:
    - Oscillations at particular frequencies or frequency bands correspond to certain brain states
    - Phase-locked (synchronized) or phase-random
    - Frequency power, frequency power over time
  - **Transient**:
    - Evoked potentials (EPs) and event-related potentials (ERPs)
    - Time-locked to an event
    - Amplitude over time

Why Use EEG?

- Quantifiable and objective measure
- Detect covert stages of processing before/without behavioural response
  - Low- vs. high-level perception and cognition
- Predictions/expectations, novelty-detection and violations
- Relate EEG signals to behavioural performance

Why Use EEG?

- **Advantages**:
  - High temporal resolution (~2 – 0.5 milliseconds)
  - Relatively low hardware and maintenance costs
  - Convenient and mobile
  - Tolerant of subject movement
  - Silent – ideal for use with auditory stimuli
  - Can be used with subjects who cannot go into an MRI scanner (e.g. claustrophobic, metal implants)

Why Use EEG?

- **Disadvantages**:
  - Significantly lower spatial resolution than fMRI
  - Cortical bias – difficult to detect signals from subcortical regions
  - Source localization (inverse problem) – sum of signals emitted from many different sources
  - ERP studies require relatively simple and limited paradigms with a large number of trials
  - Minor subject discomfort – skin abrasion, gel in hair

EEG Equipment and Supplies

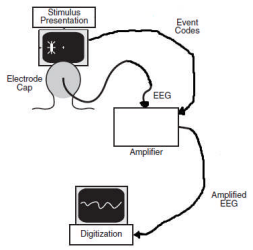
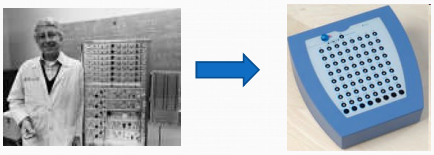


Image source: Luck, S. (2005). An Introduction to the Event-Related Potential Technique (Cognitive Neuroscience). MIT Press.

EEG Equipment and Supplies

- Our Department's amplifiers
  - High sampling frequency: up to 4000 Hz for 64 channels
  - Records up to 64 channels plus auxiliary inputs
  - Cascade amplifiers for more channels



EEG Equipment and Supplies

- The Department's caps
  - WaveGuard 64 channel electrode caps
  - Active shielding (very noise-resistant)
  - Other options:
    - Infant, child, adult S-L sizes
    - Higher density (128, 256)
    - TMS, MEG, fMRI compatible
- EOG sensors:
  - Electrooculography (vertical and horizontal eye movements)

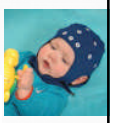


Image source: ANT Neuro website, www.ant-neuro.com

EEG Equipment and Supplies

- Consumables
  - Electrode gel, syringes, blunt needles, EOG sensor stickers
- Participant clean-up
  - Towels, shampoo/conditioner, hair dryer, etc.
- Cap clean-up
  - Water Pick (pressurized water)

Collecting EEG Data

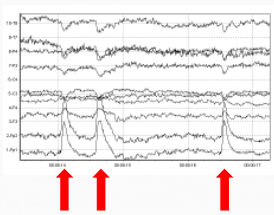
1. Place the EOG and any reference electrodes
2. Fit the cap
3. Add gel to electrode sites
4. Check impedances (kΩ)
5. Collect the data
6. Clean the cap

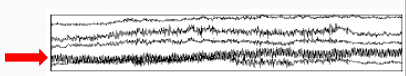
Email me for hands-on EEG data collection training!
becky.prince@york.ac.uk

Image source: ANT Neuro website, www.ant-neuro.com

Common Problems: Noise

- Signal-to-noise ratio (SNR)
  - Increase number of trials
  - Reduce sources of noise
  - Use filters
- Artefacts (sources of noise)
  - Biological
  - Environmental





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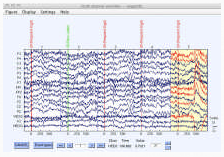
Common Problems: Noise

- Biological
  - Electrical potentials produced by muscle activity are stronger than the EEG signal



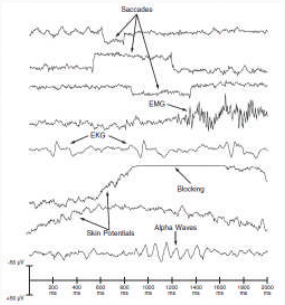
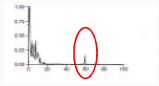
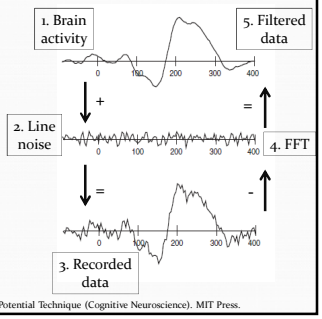


Image source: ERPLAB website, http://erpinfo.org/erplab

Common Problems: Noise

- Environmental
  - Surrounding electrical equipment (computer monitors)
  - Power supply (50 Hz alternating current in Europe, 60 Hz in US)
  - Fluorescent lights





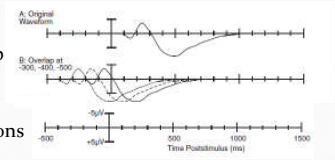
Source: Luck, S. (2005). An Introduction to the Event-Related Potential Technique (Cognitive Neuroscience). MIT Press.

Common Problems: Triggers

- Triggers (event markers) sent from stimulus computer to amplifier via parallel port or BNC
  - Add a few lines of code to your task
  - Link physical stimulus to electrical pulse (e.g. photodiode, sound card)
- Timing is critical!
  - Latency problems can be corrected
  - Acceptable amount of error depends on experiment

Common Problems: Design

- Stimuli control
  - ERP waveforms can differ due to physical characteristics of the stimuli, probability of occurrence, order, etc.
- Stimuli timing
  - Component overlap
  - Motor responses
  - Habituation
  - Setting up predictions and violating them



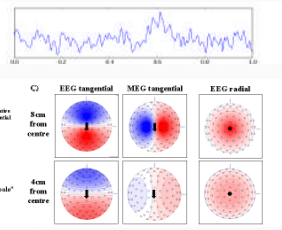
Source: Luck, S. (2005). An Introduction to the Event-Related Potential Technique (Cognitive Neuroscience). MIT Press.

Summary

- EEG is a useful tool!
  - Quantifiable measure of brain responses and states
  - Habituation, predictions, novelty/deviance detection
  - High temporal resolution - identify *when* differences occur
  - Great for cortical activity, not great for deep structures
  - Poor spatial resolution, but source localization is possible
- Easy to use, high-quality, low-cost equipment available
- If in doubt…
  - Consult recent literature on similar paradigms
  - EEG Wiki has great list of resources
  - Ask one of the many EEG-users in the Department

Thanks for listening!

What is EEG?



A) Measureable signals produced by voltage gradient in thousands of parallel and synchronized cortical dendrites

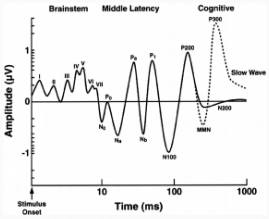
B) Dipoles (source) produce positive and negative potentials. Scalp topography depends on dipole orientation

C) Topography produced by tangential and radial dipoles. The closer the dipole is to the centre of the head, the weaker and broader the signal.

Image source: MRC CBU M/EEG website, http://imaging.mrc-cbu.cam.ac.uk/meg/IntroEEGMEG

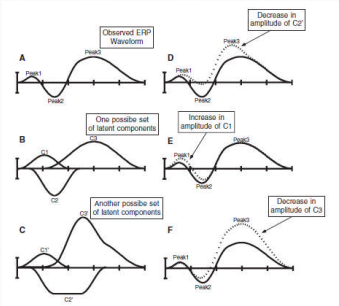
Why Use EEG?

- ERP paradigm examples
  - MMN
    - Passive response
    - ~250 ms
    - Deviance detection
  - P300/Oddball
    - Active response
    - ~250-500 ms
    - Task salience



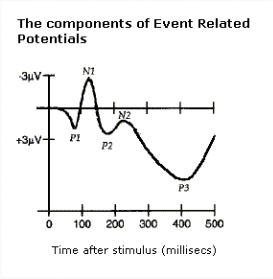
Analyzing EEG Data: ERPs

- **ERP waveforms** are the sums of separate and overlapping latent components
- **Components** are associated with specific experimental manipulations and levels of processing



Analyzing EEG Data: ERPs

- **P:** positive, **N**: negative
- Number: position within the waveform, or latency in ms
- Examples
  - **P2:** 2nd positive peak
  - **Auditory N100:** negative peak ~100 ms after auditory stimulus
  - **N170:** negative peak ~170 ms after viewing a face
  - **P3/P300:** 3rd positive peak, first discovered at 300ms but generally occurs later (250-600ms)

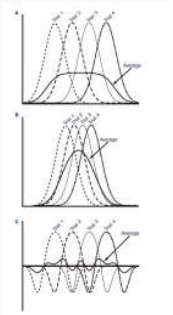


Tips for ERP Experiments

- Collect clean data!
  - Reduce and measure sources of noise
  - Increase the number of trials
- Compare the same physical stimulus across different psychological conditions
  - E.g. Block 1: **x** is target, **y** is non-target
    Block 2: **y** is target, **x** in non-target
    Compare all targets to all non-targets
  - If you must compare conditions with confounding physical differences in the stimuli, conduct a control experiment

Tips for ERP Experiments

- Make sure that there are no systematic differences between trials in the same condition
- Averaged waveforms may not be representative
  - Latency variations will distort the waveform
  - Test trigger timing



Tips for ERP Experiments

- Focus on a single, large, well-researched component
- Use difference waves to isolate a component
  - Manipulate a single specific variable
  - Take the difference between two average waveforms to isolate the component involved
- Compare conditions with equal number of trials and the same stimuli
- Remember that stimuli order and timing, and motor responses will affect ERPs

What is EEG?

Fun fact!
Any complex signal can be decomposed into a set of sine waves at given frequencies with different strengths (power) over time

Useful for understanding how recorded EEG is generated and how unwanted signals, if measured, can be removed

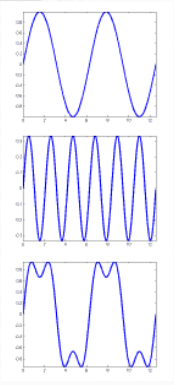
Sine wave 1

+

Sine wave 2 (3rd harmonic)

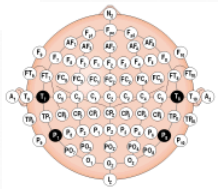
=

Starting to look more like EEG data?



EEG Equipment and Supplies

- Voltage potentials collected from cap electrodes placed at International 10-20 standard sites
  - F-Frontal, T-Temporal, C-Central, P-Parietal, O-Occipital
  - Odd - Left, Z - Zero/midline, Even - Right
  - M1/M2 - Left/right mastoids
  - A1/A2 - Left/right ear lobes
  - Nz - Nasion
  - Iz - Inion



Collecting EEG Data

1. Place the EOG and mastoid or linked ear reference electrodes
   - Prep the skin with alcohol wipes and slight abrasion to reduce impedance
2. Fit the cap
   - Measure circumference to select cap size
   - Measure nasion (Nz) to inion (Iz)
   - Mark 10% on forehead
   - Place FPZ on 10% mark

Collecting EEG Data

3. Apply gel to electrode sites
   - Use a blunt tip on the scalp to move hair and dead skin
   - Add enough gel to form a connection between scalp and electrode
   - Not enough gel = bad signal, easily fixed
   - Too much gel = salt bridge, hard to fix

Collecting EEG Data

4. Check impedances (kΩ)
   - Colour-coded system in ASA software shows you which sites need more gel and/or abrasion
5. Collect the data!
   - Add a few lines of code in E-Prime or PsychoPy to send event triggers
6. Clean the cap
   - Pressurized water
   - Disinfect

Collecting EEG Data