Basic EEG Technology

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What is EEG?

- The display of the fluctuations in voltage which occur over the scalp generated by postsynaptic potentials in cortical neurones.
- These voltage fluctuations tend to occur rhythmically, predominantly as a result of interaction between the cortex and thalamus.
- In order to be recorded at the scalp, there must be summation of synchronous potentials generated by many synapses.

Third dimension

- 3rd dimension is spatial distribution over head.
- EEG therefore measures voltage changes over time and space.

Frequency

- The variability over time is expressed as cycles per sec or Hertz (Hz).
- A number of frequency bands are arbitrarily set:

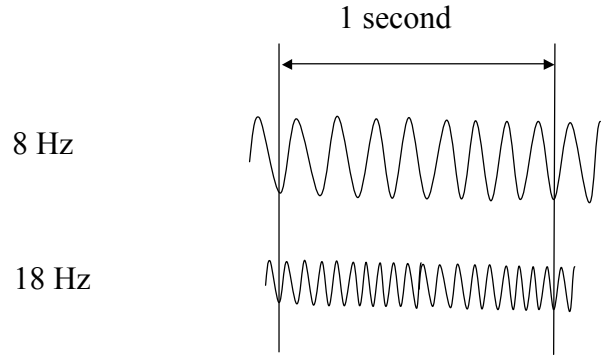
  Alpha = 8-13 Hz

  Beta = >13 Hz

  Theta = 4-less than 8 Hz

  Delta = <4 Hz

Frequency



Terms

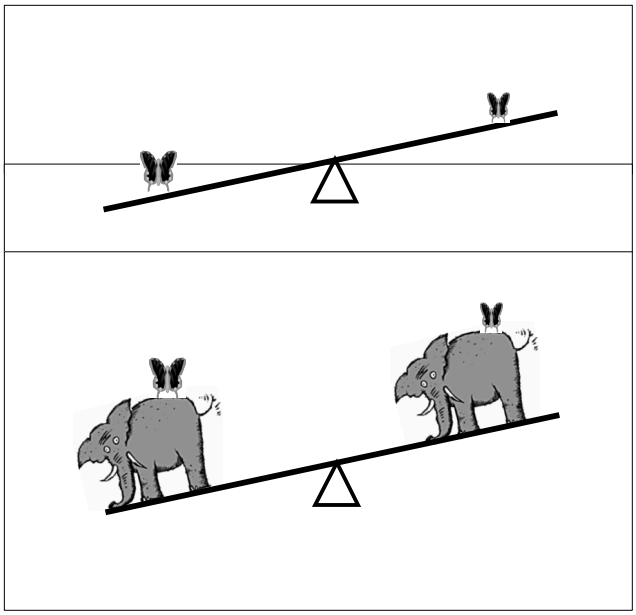
- *Amplitude* of voltage fluctuations is measured in microvolts.
- *Sensitivity* or *gain* is like the volume control on a radio.
- *Channel* = the display of voltage fluctuations between a single pair of electrodes
- *Montage* = a collection of channels displayed in a topographically logical order

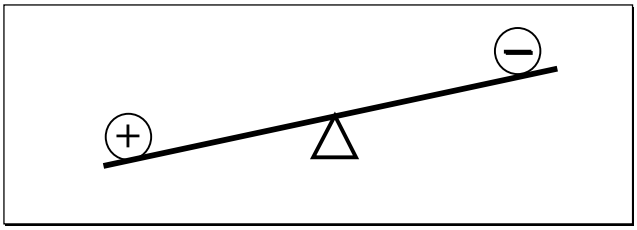
Differential Amplifiers

- Measure *difference* in potential (voltage) between two points
- They do not measure absolute values
  - Measuring the height of the waves on the sea tells you nothing about the depth of the water.
  - Measuring the vertical distance between two aircraft tells you nothing about their altitude.

Common Mode Rejection

- Because differential amplifiers record only *differences* between inputs, anything which affects voltage equally at both inputs will not be “seen” but “rejected”.





Common Mode Rejection

- CMR is useful
  - to record localised activity
  - to eliminate some artifacts e.g. 50Hz AC
- CMR can be misleading when activity is widespread, by making it appear localised

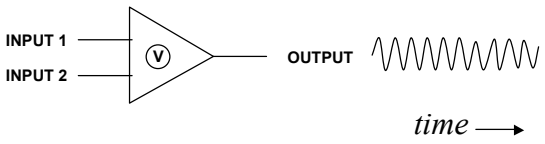
Differences

- More tall = less short
- More short = less tall
- More heavy = less light
- More light = less heavy
- *More positive = Less negative*
- *Less positive = More negative*

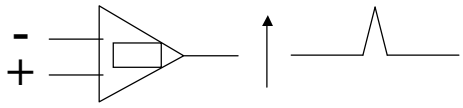
Differential Amplifiers

- The amplifier cannot tell the difference between a negative event at input 1 and a positive event at input 2

Differential Amplifiers



Polarity Convention



L1 NEGATIVE UP
"LINEUP"

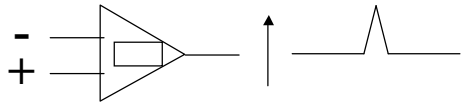
Polarity Convention

L1 MORE NEGATIVE UP
"LINEUP"

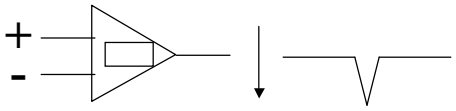
L2 MORE POSITIVE UP

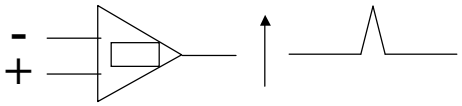
L1 MORE POSITIVE DOWN

L2 MORE NEGATIVE DOWN



L1 NEGATIVE UP
"LINEUP"





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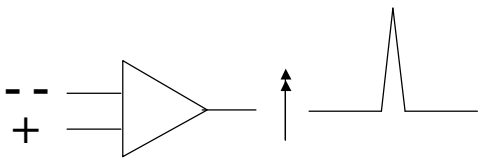

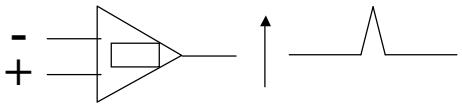

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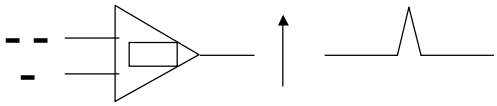

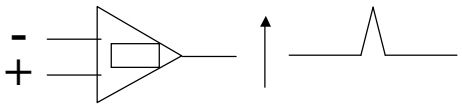

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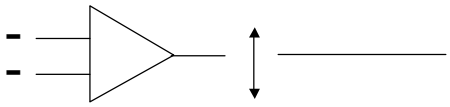

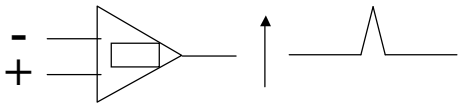

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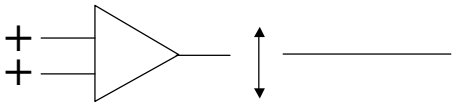

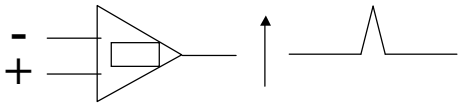

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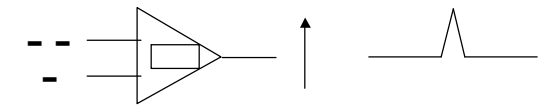
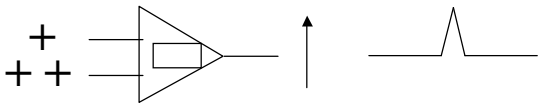
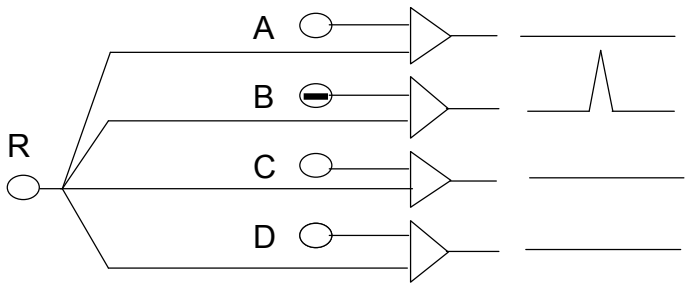




Referential recording

- Each amplifier requires 2 inputs.
- We cannot tell whether a voltage fluctuation is due to a change at input 1 or input 2.
- The aim is to find an inactive point against which to measure voltage fluctuations.
- If we measure multiple points on the head against the same inactive (reference) point, we can see the topographical distribution of various frequencies.
- Such a point does not exist!
  (but there are good approximations)

Referential recording

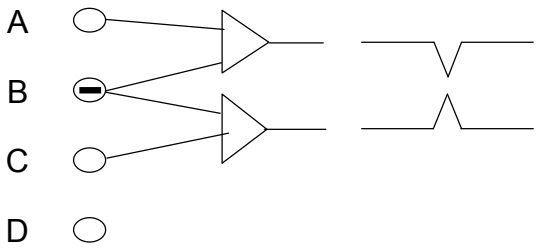


Input 2 of each amplifier is connected to a common electrode (the *reference*)

Phase reversal

- Simultaneous “pen” deflections in opposite directions in different channels

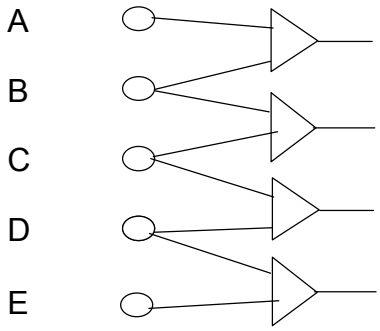
Phase reversal



The same electrode is connected to *Input 2* of one amplifier and *Input 1* of the next amplifier.

An event at the shared electrode will therefore produce deflections in opposite directions at the two amplifiers.

Bipolar chain

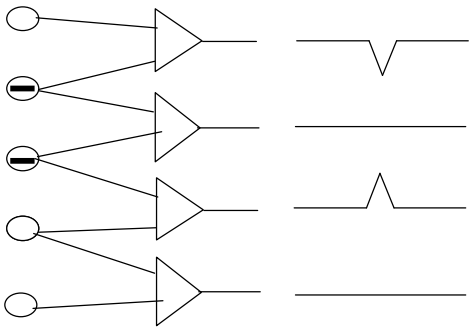


Input 2 of one amplifier is also *Input 1* of the next amplifier

Phase reversal

- Is *not* an abnormality - many normal phenomena show phase reversal
- Is a device to draw the eye to a localised voltage change

Equipotential electrodes

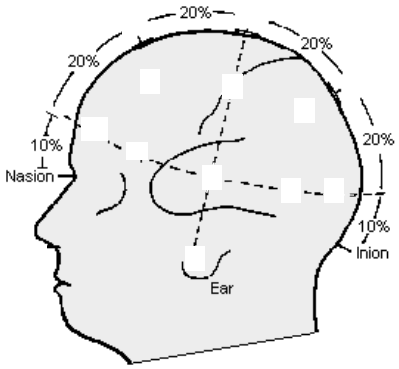


A flat line does *not* mean nothing is happening!

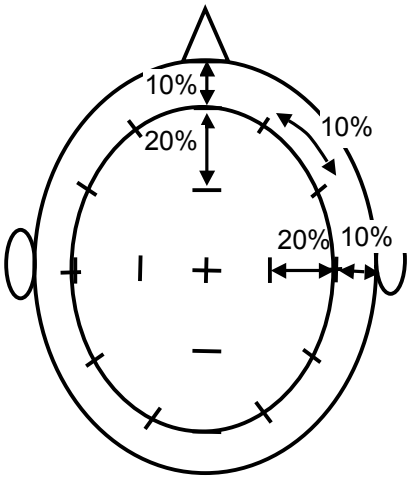
Inter-electrode distance

- Amplitude increases with increasing distance between electrodes
- Not important beyond 10 cm
- 10-20 system of electrode placement aims for equal inter-electrode distances

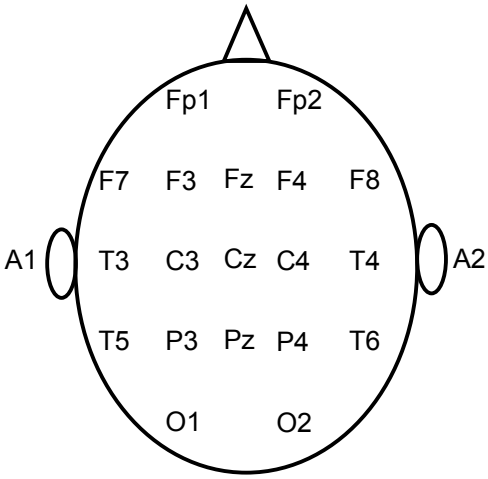
10-20 System



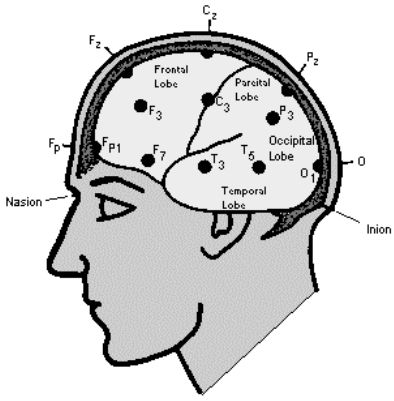
10-20 System



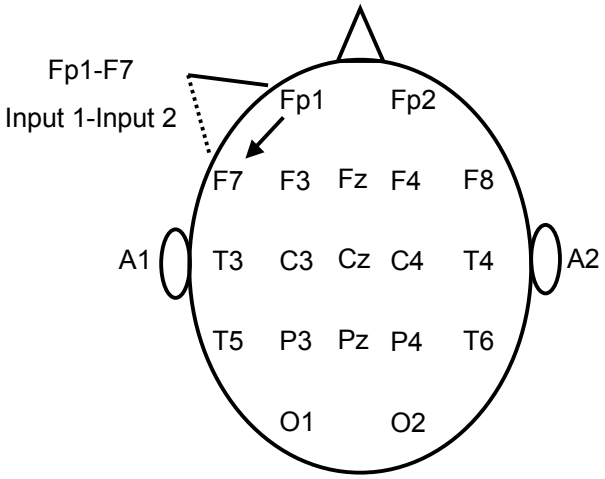
10-20 System



10-20 System



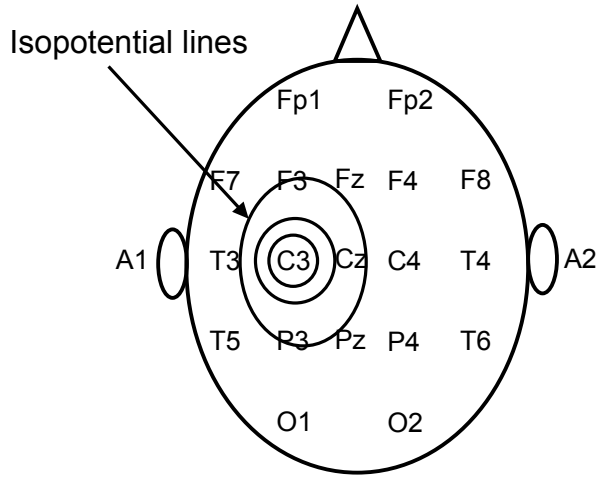
Channel Notation



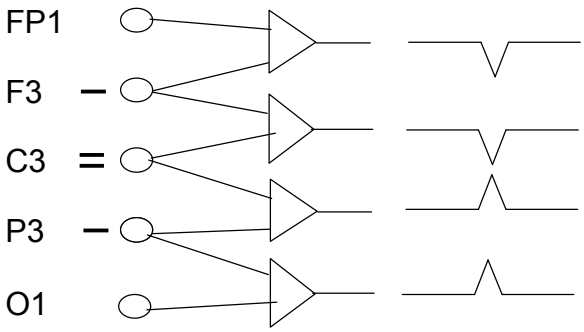
Field

- Field refers to the spatial distribution of voltage over the scalp.
- The maximum usually involves one or two electrodes. Surrounding electrodes are affected to a lesser degree.

Field

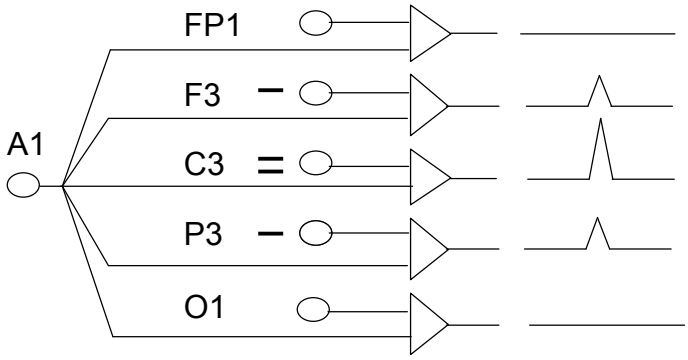


Field - Bipolar recording



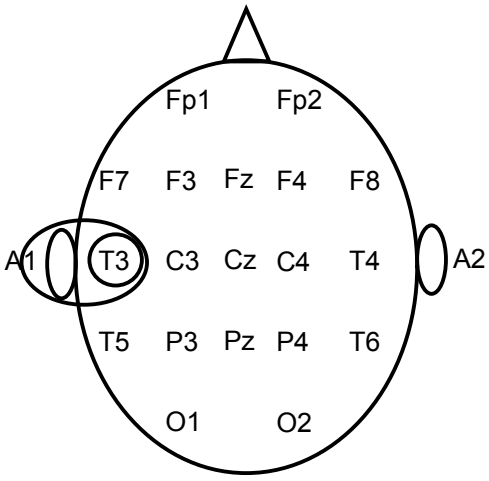
Input 2 of one amplifier is also *Input 1* of the next amplifier

Field - Referential recording

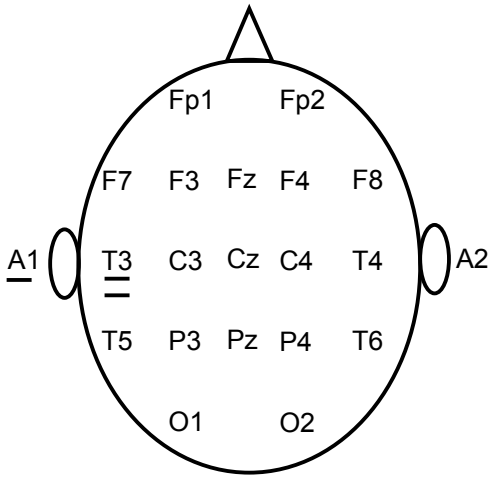


Localisation is by amplitude, not phase reversal

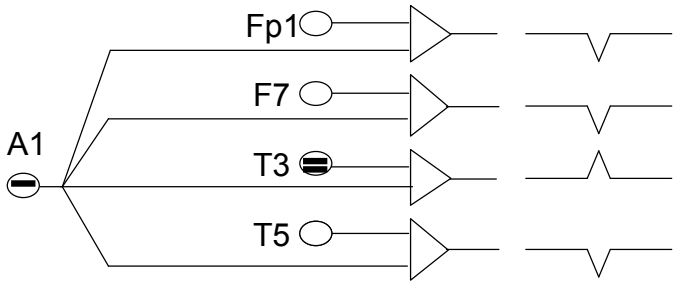
Field



Field



Active (“Contaminated”) Reference



Patient comfort

- Desirable to reduce EMG artifact and to promote sleep
- Electrode type - discs not cap & pad
- Position - lying not sitting
- Environment - quiet and dark
- Skillful technician

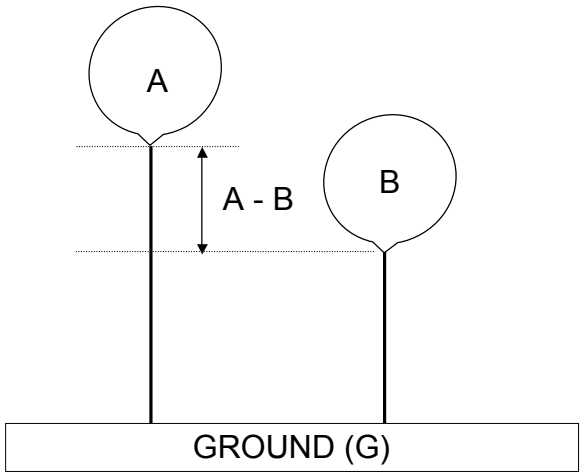
Reformatting montages

- Allows you to recreate any montage *after* the recording is finished.
- Each electrode is referred to a common reference.

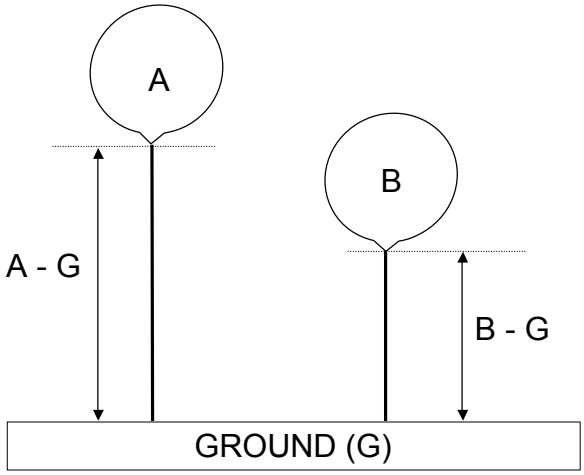
Reformatting montages

- Two helium filled balloons are tied to the ground with strings of different lengths.
- We want to know what the vertical separation of the balloons. How do we do it?
- A) We could try to measure it directly or
- B) We could measure the length of the strings and subtract them.

Reformatting montages

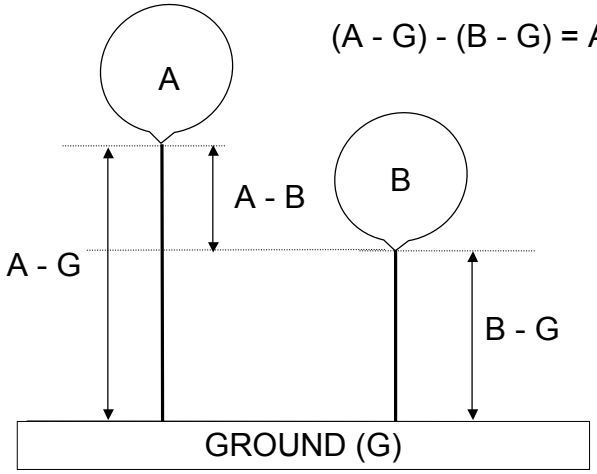


Reformatting montages



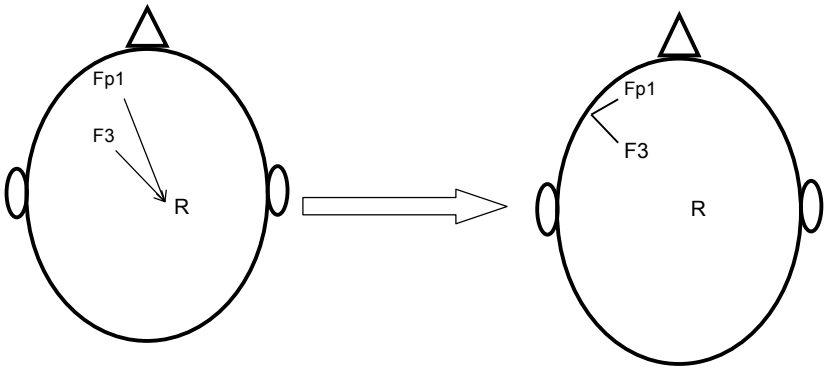
Reformatting montages

(A - G) - (B - G) = A - B



Reformatting montages

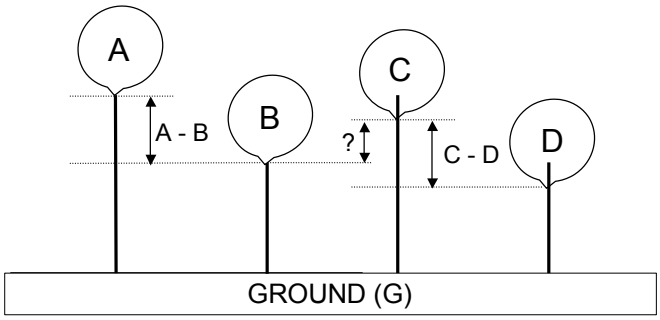
- (A - G) - (B - G) = A - B
- (Fp1 - R) - (F3 - R) = Fp1 - F3



Reformatting montages

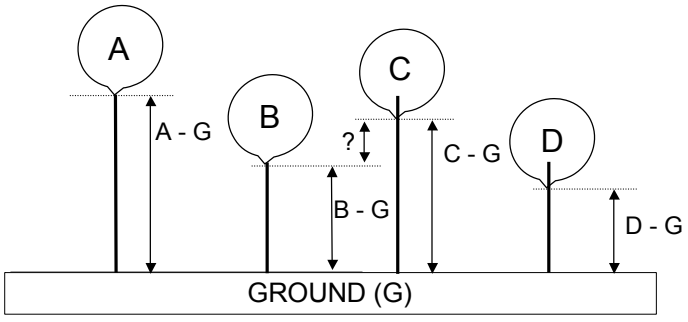
- The purpose is to allow the montage to be reformatted *after* the recording.
- Each electrode is referred to a common reference.
- We are then able to subtract any channel from any other channel to create a new channel.

Reformatting montages



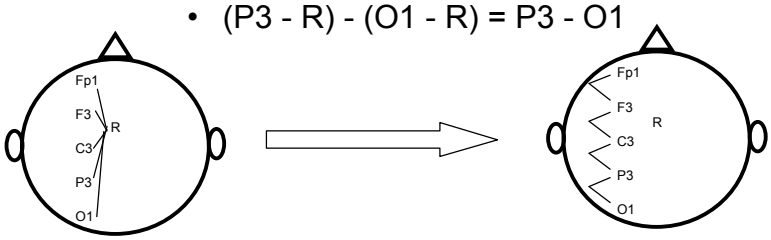
Reformatting montages

(B - G) - (C - G) = B - C



Reformatting montages

- (A - G) - (B - G) = A - B
- (Fp1 - R) - (F3 - R) = Fp1 - F3
- (F3 - R) - (C3 - R) = F3 - C3
- (C3 - R) - (P3 - R) = C3 - P3
- (P3 - R) - (O1 - R) = P3 - O1



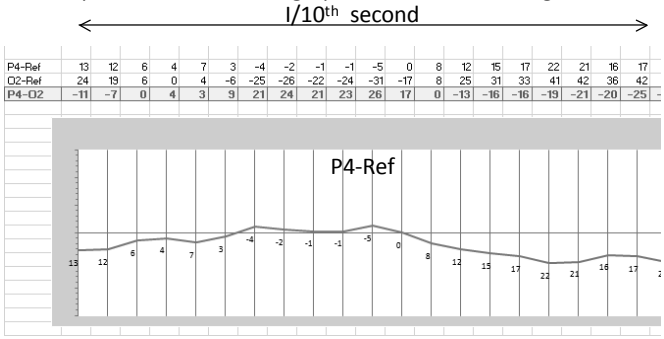
Digital EEG

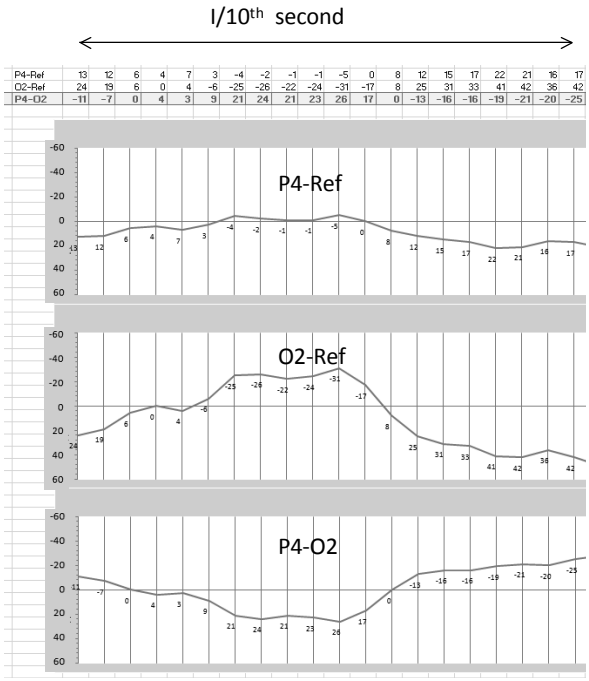
Digital EEG measures voltage between each electrode and a common (shared) reference electrode and stores it in the computer as a number.

To obtain the voltage between any 2 electrodes (e.g. P4-O2), the computer subtracts the numbers corresponding to each electrode. e.g. P4-O2 = (P4-Ref) – (O2-Ref). This yields another number.

It does this at least 200 times per second. This is referred to as a sampling rate of 200 Hz.

The computer screen draws a graph of these numbers against time.





Reference Electrodes

- Ipsilateral ear
- Linked ears
- Cz
- Chest
- Balanced neck-chest
- Average
- Source derivation

Reference Electrodes

	Pros	*Cons*
Ipsilateral ear	**Relatively inactive**	**Contamination by temporal activity** **EMG, ECG**
Linked ears	**As above** **Little ECG**	**As above**
Cz	**Little EMG** **Distant from temporal regions**	**Contamination by sleep activity**
Chest	**Non-cephalic**	**ECG**
Balanced neck-chest	**Non-cephalic**	**Demanding**
Average	**Minimises distant activity**	**Conceals widespread activity** **May be contaminated**
Source derivation	**As above**	**As above**

Filters

- A device to attenuate unwanted frequencies
- Not there to make EEG look pretty
- Not there to compensate for or conceal poor technique
- There is always some loss of data

Filters

- The importance of the slow end of the frequency spectrum has been diminished by modern neuro-imaging
- The significant frequencies are 1-70 Hz

Filter types

- Low frequency (LFF) / High pass
- High frequency (HFF) / Low pass
- Notch / Band reject
- Band pass

Filter settings - what they mean

- The frequency corresponding to the filter setting is attenuated by about 30% - it is not blocked completely.
- Frequencies beyond the filter setting will be attenuated to a progressively greater degree
- Roll-off refers to the shape of the frequency-attenuation curve

Uses of filters

- LFF attenuate slow artifacts (incl SEMs) which then allows higher sensitivity display of remaining activity
- HFF attenuate EMG
- Notch filter attenuates AC interference (50 Hz)

Shortcomings of filters

- Distort wave-forms
- May conceal pathological activity
- May conceal faulty electrode
- May conceal useful artifacts

Filters

Should be used intelligently, not arbitrarily!

Volume Conduction

- Transmission of current through the tissues between the generating cells and the recording electrode (brain, CSF, meninges, bone, etc)
- Occurs at the speed of light
- May account for activity recorded from distant electrodes

Remember!

- Each EEG channel displays the *difference* between 2 points
- Line 1 negative → upward deflection ("LiNeUp")