The electroencephalogram (2)

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Topics

- Overview
- EEG instrumentation
- Practicalities of data collection
- Artifacts
- EEG analysis

Reference: Hari and Puce. *MEG-EEG Primer*. Oxford University Press. 2017

Data Collection

General Principles of Good Experimentation

When you acquire EEG signal, they are very small.

- Record EEG data from alert and cooperative subjects in as artifact- and noise-free conditions as possible.
- Divide the recording session to smaller “runs,” or blocks,

It's a continuous flow of inunterrupted signals

- Remind subjects about relaxing their muscles, minimizing blinking, and avoiding head and body movements.
- Monitor the brain signals continually online for any artifacts or technical issues

It is exremely important that you don't just wear the elctrodes on your subject, start the recording and go back when it is finished. Monitoring recording is really important.

Electrodes, Skin Preparation, and Electrode-Impedance Measurement

- General subject preparation.

The quality is better because when you wash your hair and you eliminate the scores and the dirth, this reduces the impedance between the elechtrodes and the skin itself.

  - ask subjects to **wash their hair** (and skin) prior to arriving for an EEG study and to refrain from applying any cosmetic products on the skin or hair/scalp,

- Skin preparation and electrode application.
  - Most electrodes have a hole at the top where **conductive gel** can be inserted with a blunted needle/syringe
  - The blunted needle also allows light **abrasion of the skin** of the scalp to be performed, if needed.
  - Following skin preparation, **impedances** of less than 5-10 kΩ can be easily obtained

Low impedance is mandatory for a good recording.

- Electrode-impedance measurement.

Planning and logging

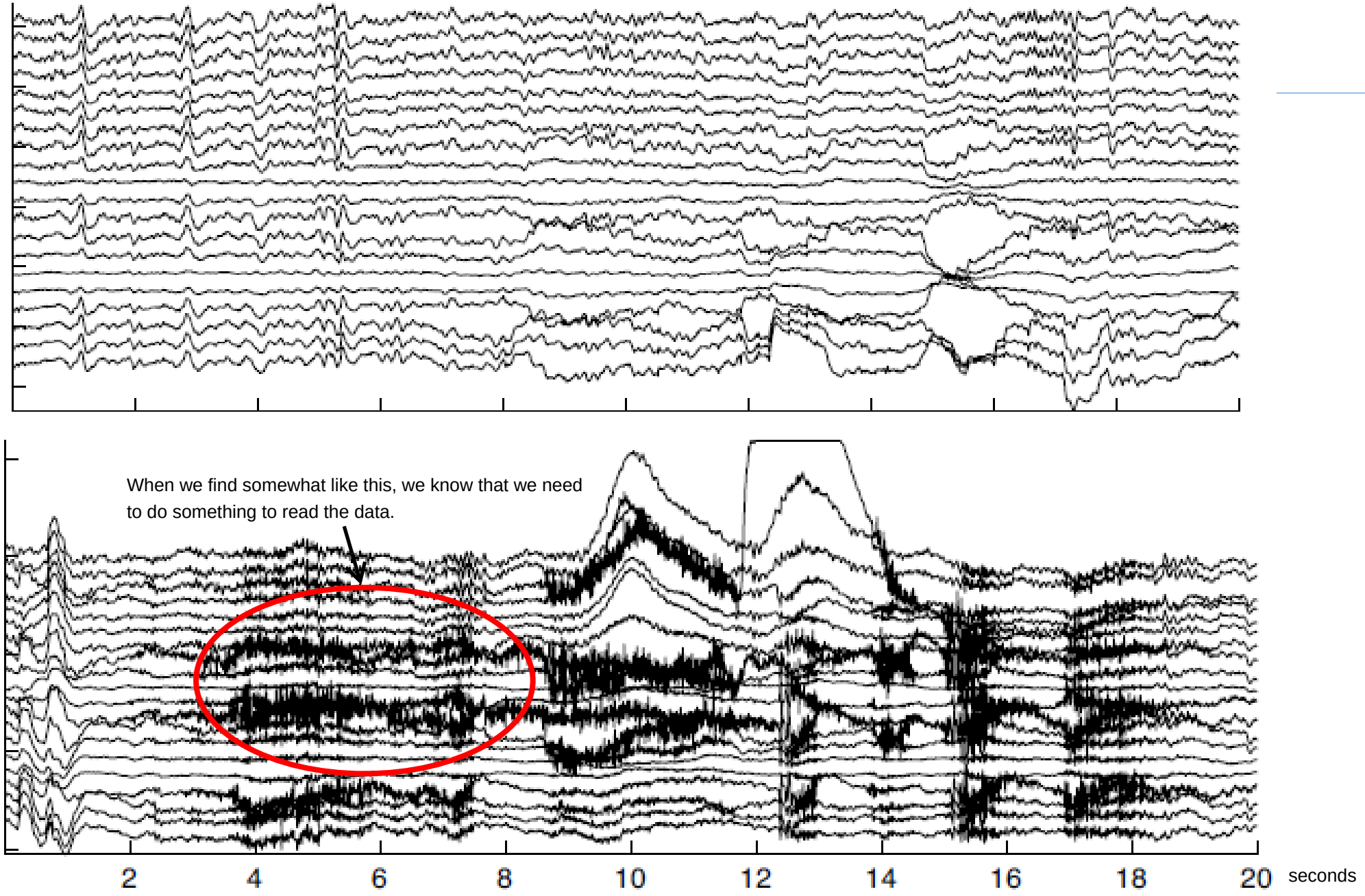
- Scientific experiments have strict protocols
- Even if conducting an exploratory session, you still need to
  - plan your recording
  - accurately log the conditions occurring in each run
  - Possibly save explanatory metadata (e.g. time markers) with the data

Usually the acquisition system, the amplifier itself, has a software switch so that you can either record and amplify the signal.

This is technical term. It means that there is something that produces elechtrical activities which is not the brain, and this activity is recorded together the data and makes it diffucult to read the EEG data. We need to avoid the generation of artifacts.

Artifacts NOISE

2 EEG traces.


When we find somewhat like this, we know that we need to do something to read the data.
2
4
6
8
10
12
14
16
18
20
seconds

Introduction

- An artifact in EEG can be defined as any potential difference due to an extracerebral source ↗Def
- We can distinguish the artifacts of technical and biological origin.
  - Technical: power supply, spurious electrical, noise from electrical engines, bad electrode contact, or its detachment, saturation of the ADC. ↗Ex. of technical artifact
    ANALOGICAL TO DIGITAL CONVERTER
  - Biological: eye blinks, eye movements (EOG), muscle activity including swallowing and teeth clenching (EMG), electrocardiogram (ECG). →ELECTROOCULOGRAM
  - Body and head movements may induce not only muscle electrical activity, but also slow potential shifts due to the physical displacement of the ions double layer on the electrode surface.

Eyes produce lots of artifacts. Both when you blink and you move your eyes, your muscles (EMG) produce lots of elechtrical signals and we have the EMG

If you move your elechtrodes or you change the composition of the gel, you may see very low and large potential

Prevention of artifacts is always preferable to removing or compensating for them post hoc during data analysis.

Physiological Artifacts

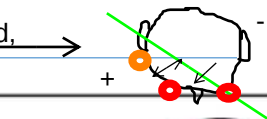
- Eye-related
- Muscle artifacts
- Cardiac artifacts
- Sweating artifacts

EOG

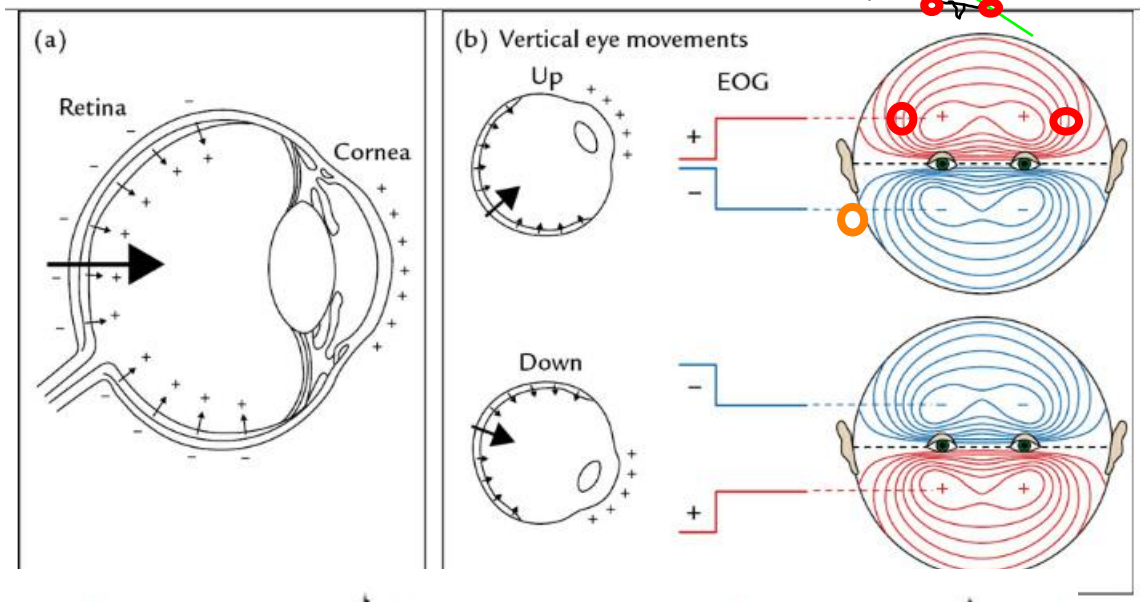
Eye-Related Artifacts

Your retina is a sensitive to the light part. It has a double layer and it is charged positively in the internal parte of the eye and negatively in the external. If you move your eyes you change the potential.

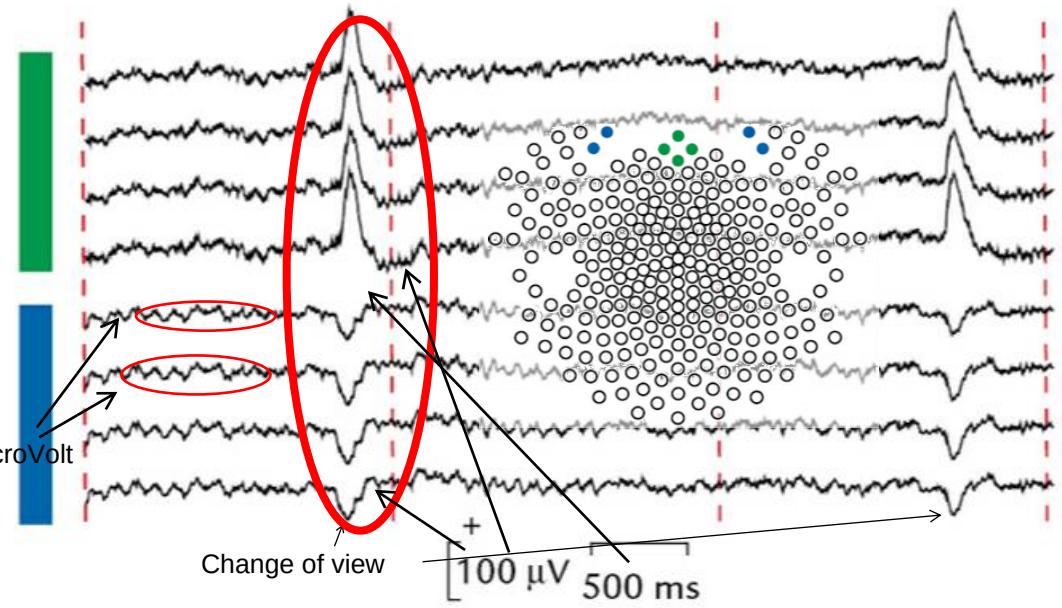
If you have 2 elchtrodes (red circles that are positive) in this position and you are observing from the orange circle. What happen if you look at right? If you look the head overhead, when you look at right you are in the positive potential region. At left otherwise. The line is the zero potential line.



- Ocular artifacts arise because the eye is an electrical dipole, with the cornea positively charged with respect to retina at the back of the eyeball
- During **eye movements**, the eyeball moves within the volume conductor. These ocular artifacts are of the order of 0.5 mV.

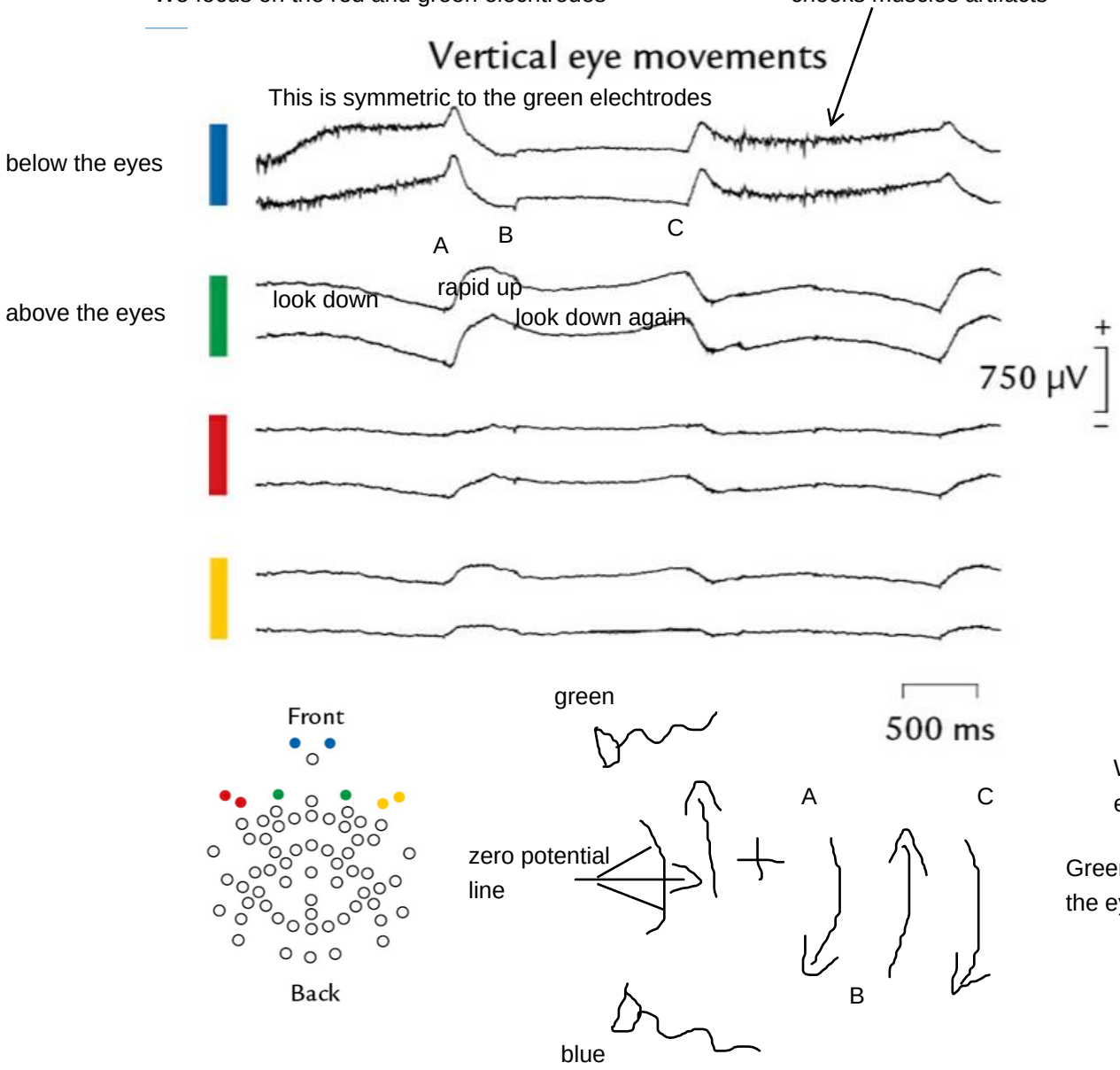


- During **eye blinks**, the volume conductor changes because of movements of the eyelids that due to their moist inner surface provide a well-conducting pathway for current flow.
- 0.5 mV, monophasic, 200-400 ms

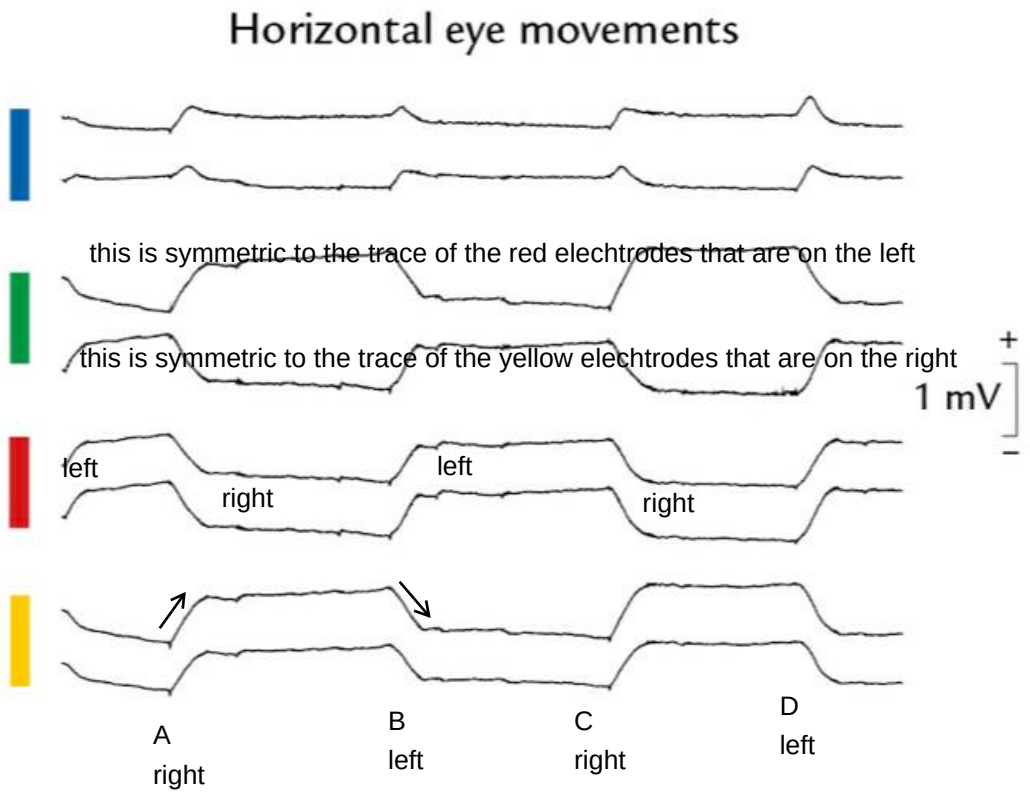


We focus on the red and green elechtrodes

cheeks muscles artifacts



We focus on the red and yellow elechtrodes.



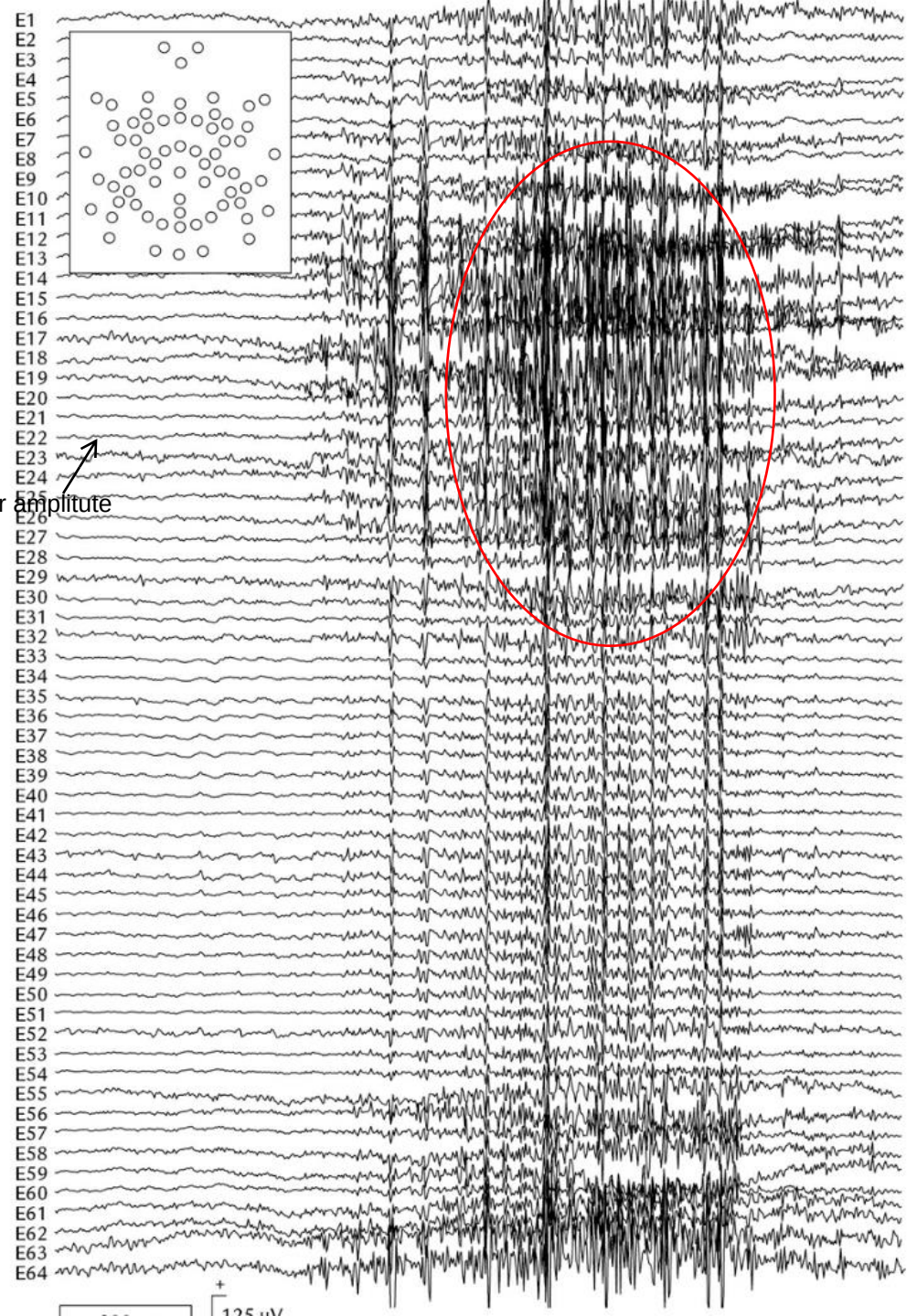
When the peak is positive we know that the subject is looking in the direction on that elchtrod.

Green trace is influenced from yellow and red elechtrodes traces. While the blue trace below the eyes follows the eye movement, it's that the elechtrod position is the zero potential line.

Muscle Artifacts

- Muscle contractions are seen as artifacts in the 100-µV or 1-mV range, with a wide frequency spectrum from tens of Hz to a few kHz, thereby in the same frequency range as beta- and gamma-band signals

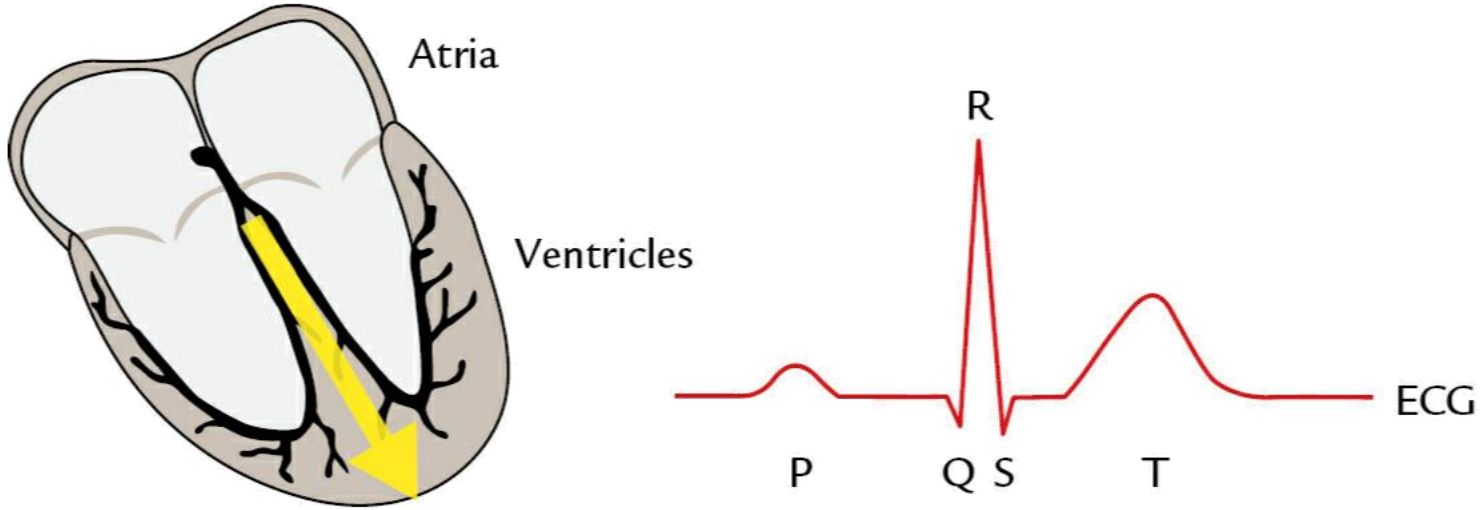
- The experimenter should always ask the subject to relax the muscles and carefully inspect the EEG traces to check for contamination
  - Despite the instructions, subjects may be unable to relax and release muscle tension.



64-channel EEG recording

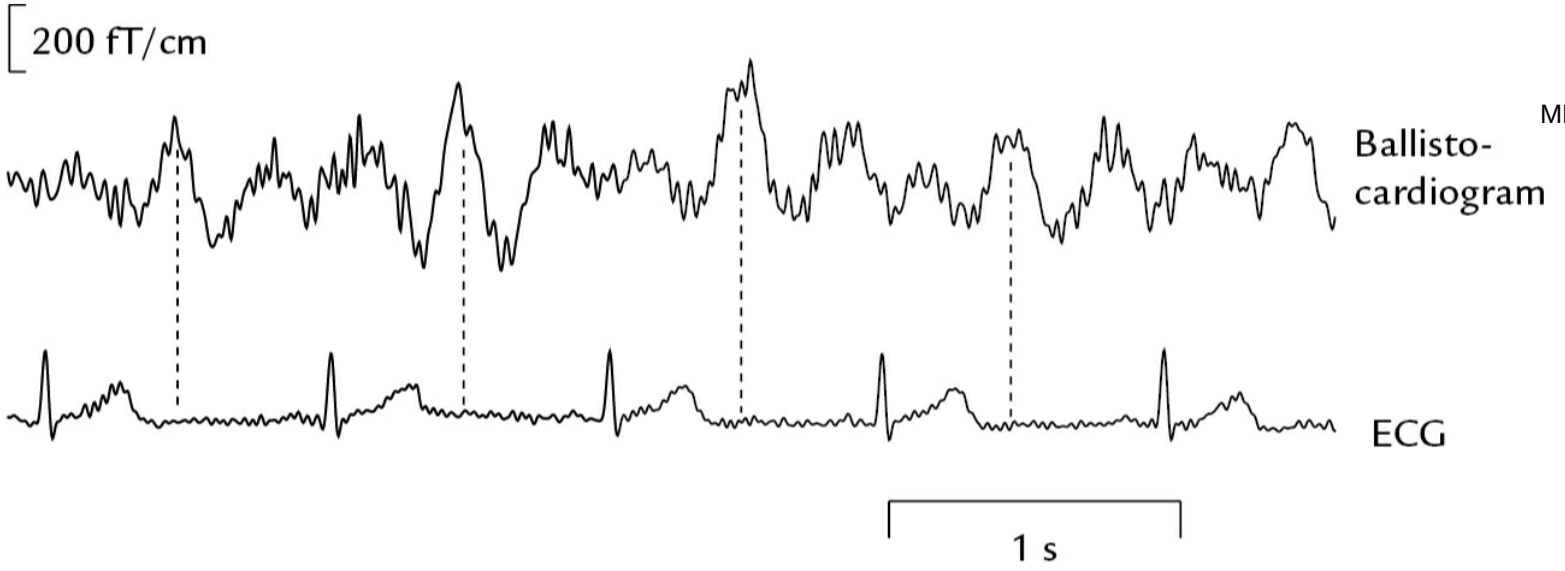
Cardiac Artifacts (1)

- Electric potentials generated in the heart can be easily recorded, and are known as the electrocardiogram (ECG)
  - In the literature they can also be referred to by the German-derived acronym EKG
- In EEG recordings using noncephalic reference electrodes prominent ECG artifacts occur
  - Less so when the EEG reference is placed on the subject's head



Cardiac Artifacts (2)

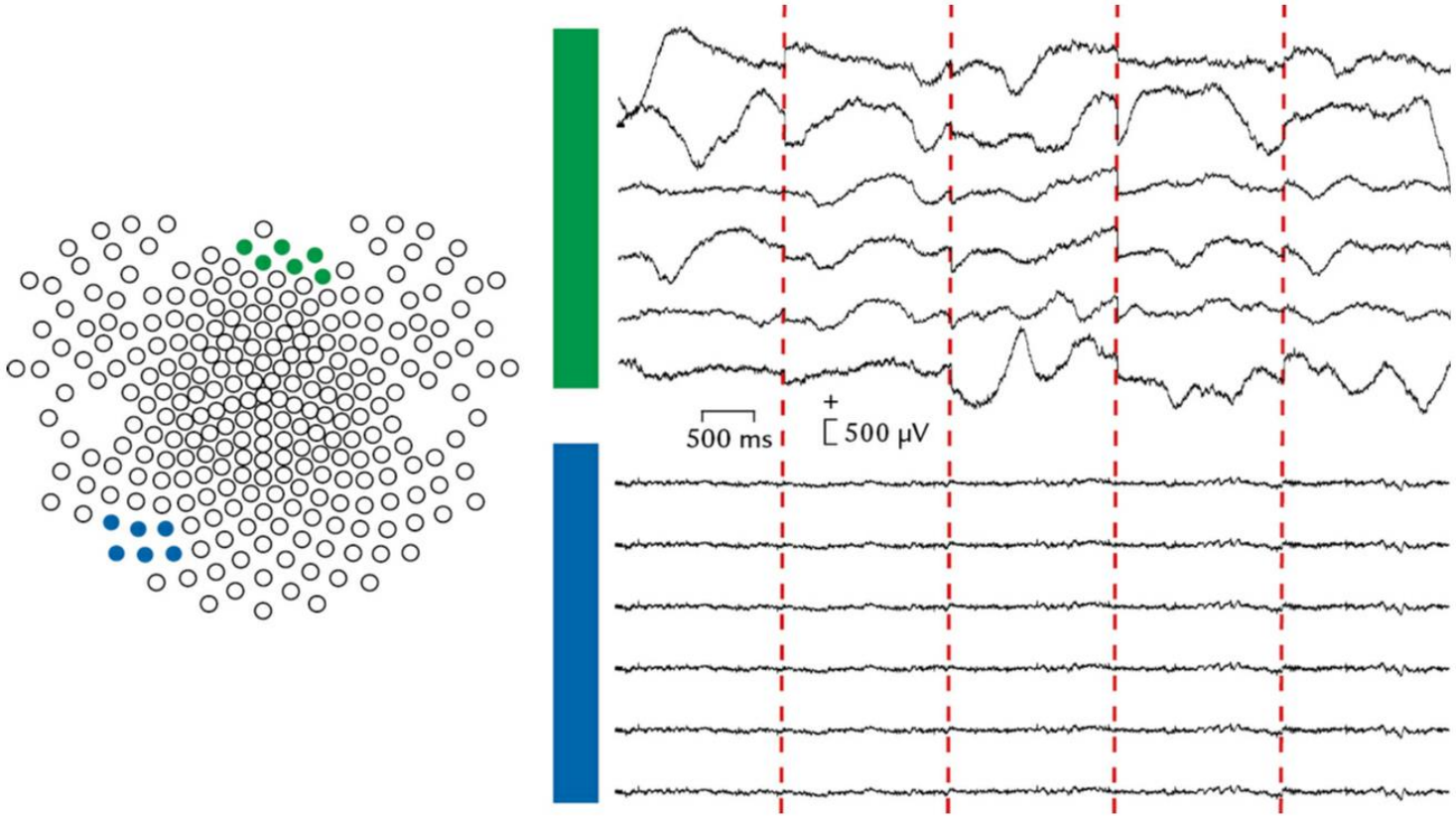
- Another important cardiac-cycle-related artifact in EEG data results from the ballistocardiogram that reflects small electrode movements due to a nearby blood vessel in the scalp.
  - This artifact is usually clearly visible during online monitoring, and it can be eliminated by moving the EEG electrode a small distance.



MEG: megnetoencephalography

Sweating SUDORAZIONE

- Sweating can be a problem in EEG recordings as it is accompanied by electrodermal responses, high-amplitude slow (< 0.5 Hz) potentials



Nonphysiological Artifacts

- Powerline
- Electrode-related
- Motion artifacts

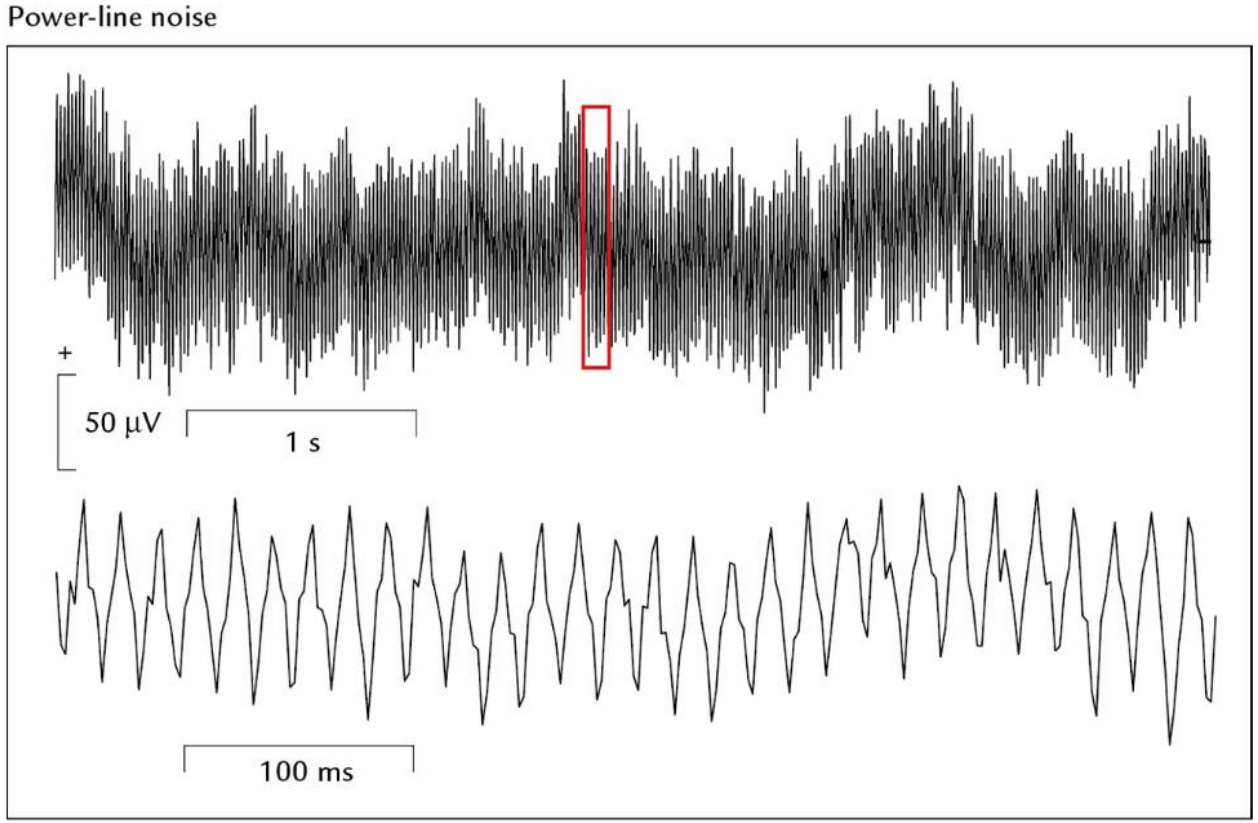
They are not due from biological souces but from other elchtrical sources

Line noise

The best way to remove these artifacts is, as usual, not to eviting the traces. So to do that you make sure that the impedance of the elechtrod is low. Another way is to use a specific filter, it is a notch filter. It is a filter that eleminates a specific frequency. when you use it, you eliminate only signals at this specific frequency.

- "Line" (power-line) noise arises from the capacitive coupling of alternating current supplied to electrical wall outlets.
- the line noise occurs either at 50 Hz (or 60 Hz) and at their harmonics.
  - Thus, in the time domain, the signal is not necessarily a sinewave

- It is accentuated in EEG electrode pairs that have an impedance mismatch (reduced CMRR)
- Unless there are no other alternatives, a digital notch filter set to the appropriate line frequency (and its harmonics, if necessary) can remove this noise

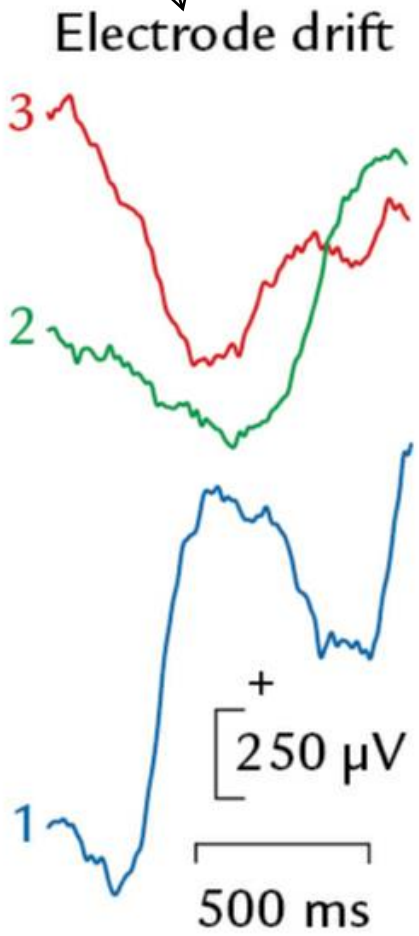


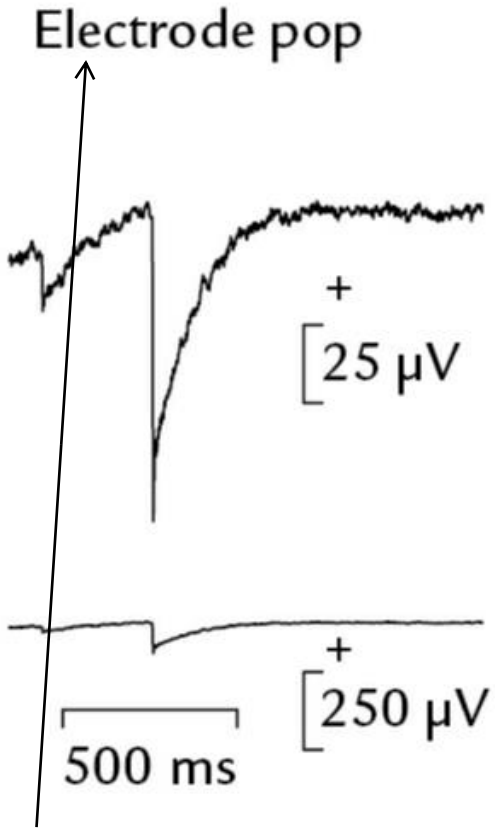
Electrode-Related Artifacts

Sometimes it can happen that all your channels are good but there are 1 or 2 channel that are behaving differently. It means that you see something like sweating, and you see that one elchtrod is going up and down like 1, or 2 and 3.

- A number of different artifacts can arise from improperly applied EEG electrodes.
  - "Bad electrode" artifacts as very slow baseline drifts
  - Electrode "pop" is an intermittent phenomenon that appears as a sharp, sudden rise followed by a gradual fall in the EEG signal of a single electrode

- In EEG recordings, artifacts can be created by the experimenter's movements around the subject, and this problem can be exaggerated in dry air environment creating a problem with static electricity.





It may happen because there is an accumulation of capacity in an elechtrod.

Movement artifacts

- At the interface between metal (electrode) and ionic conductor (gel/skin) there is a displacement of ions that resembles a capacitor
- Movement of the electrode (e.g. produced by movements of the subject's head) disturbs the geometry of the «capacitor», producing a relatively strong potential