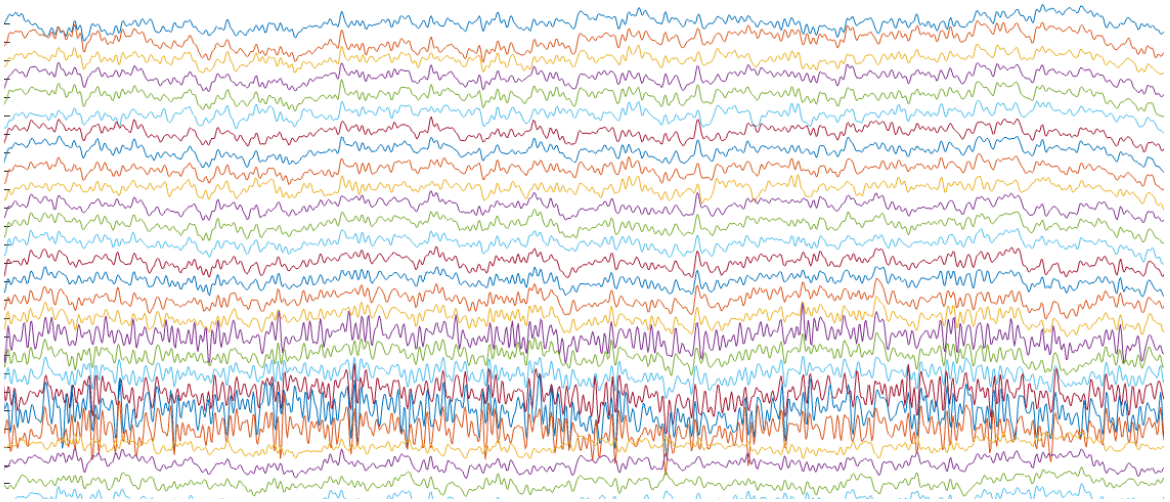
Introduction to EEG

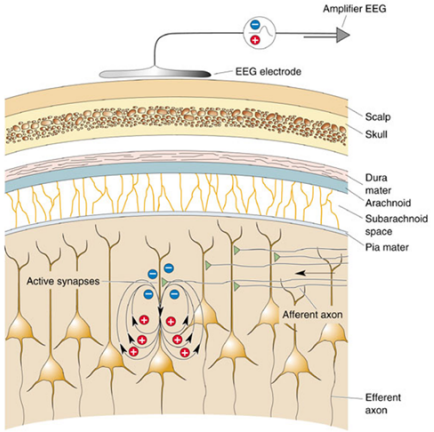
Kiel Open Science School, 25-27.02.2019

Wokshop : Fiedtrip Toolbox for EEG analysis



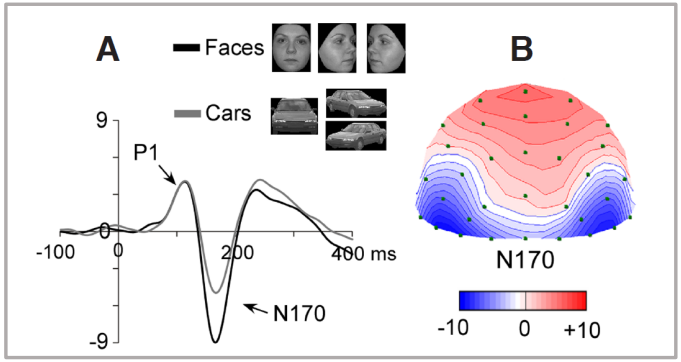
Content

What is EEG?



How we measure EEG?

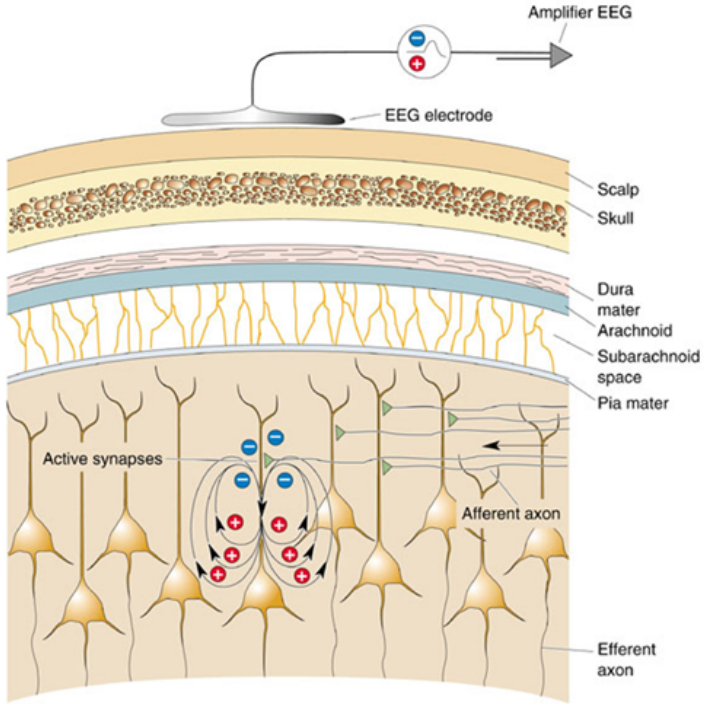
Analysis of EEG



Rossion and Jacques, 2011, *The Oxford handbook of ERP components*

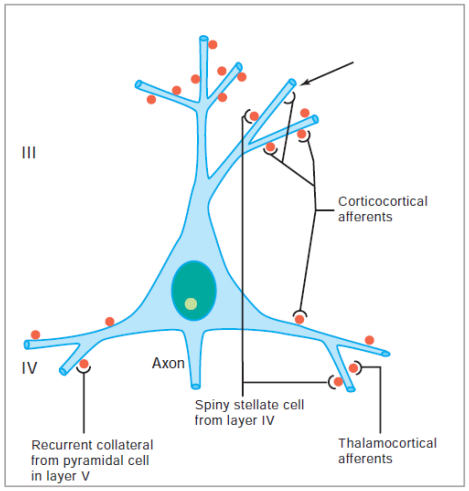
What is Electroencephalography (EEG)?

- EEG is the recording of the brain **electrical fields**
- The electrical fields are the result of **electrochemical signals** passing from one neuron to the next.
- When **billions** of these tiny signals are passed **simultaneously** in spatially extended and **geometrically aligned neural populations**, the electrical fields sum and become powerful enough to be measured from outside the head.



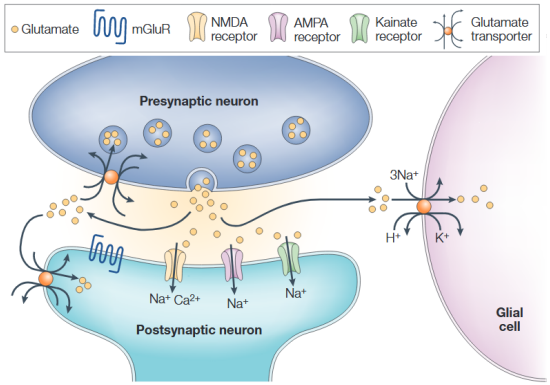
What is Electroencephalography (EEG)?

Neurons form synapses



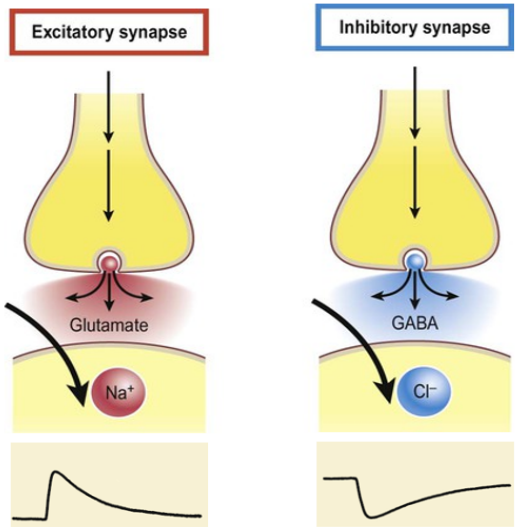
Spruston, 2008, *Nature Reviews Neuroscience*

Synapses enable communication



Attwell and Gibb, 2005, *Nature Reviews Neuroscience*

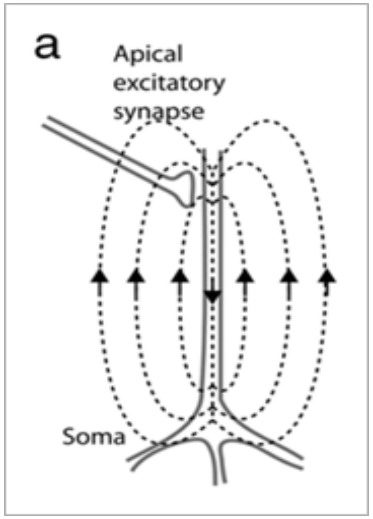
Synapses can give rise to tiny electrical signals



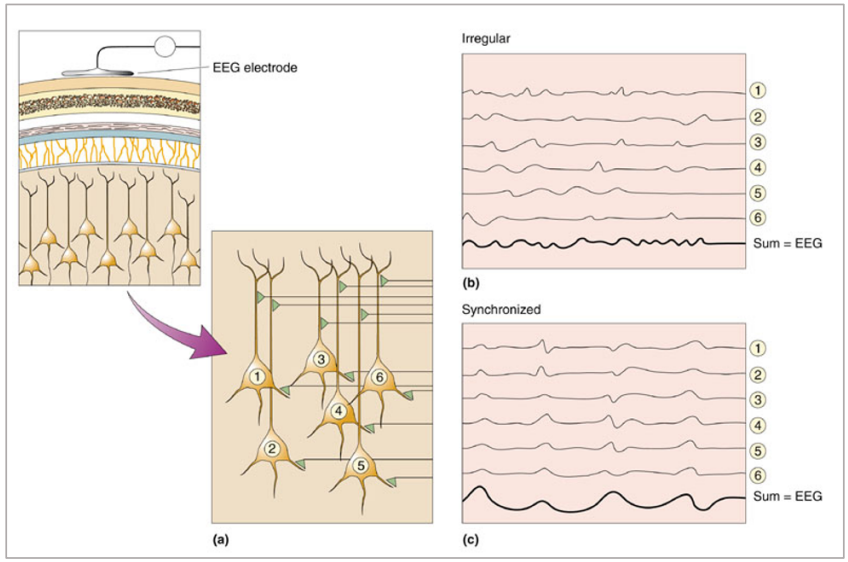
Excitatory Postsynaptic Potential (**EPSP**)

What is Electroencephalography (EEG)?

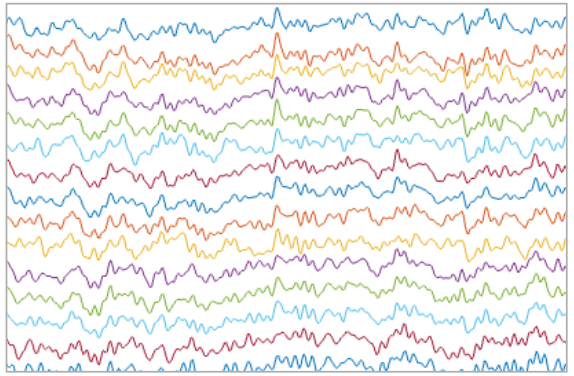
(Tiny) electrical signals (EPSP) create (tiny) dipoles



Many (pyramidal) neurons
Spatially Aligned
Fire simultaneously



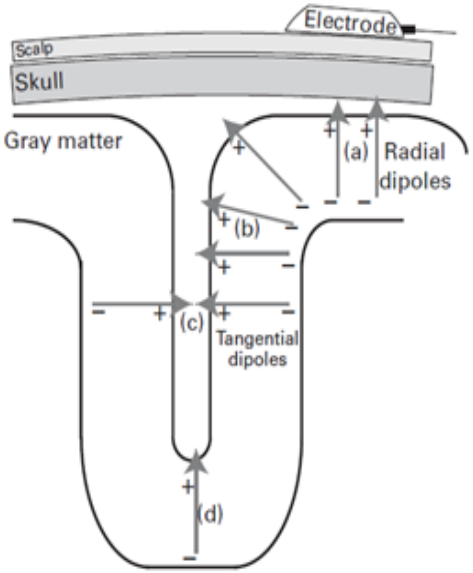
Big dipole / strong electrical potential is picked up by EEG electrodes



Barrès et al, 2013, *Neural Networks*

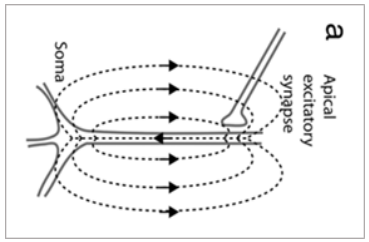
What is Electroencephalography (EEG)?

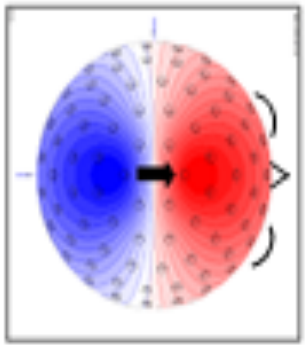
Big dipoles can be parallel or vertical to skull surface



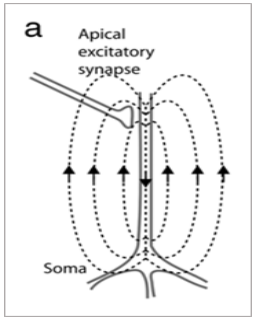
Cohen, 2014, Analyzing neural time series data, MIT

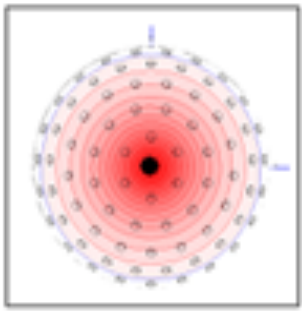
Parallel (**tangential**) diapoles produce bipolar current distribution





Vertical (**radial**) diapoles

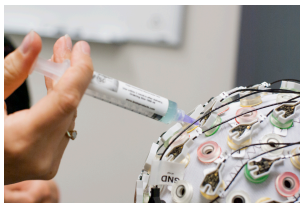




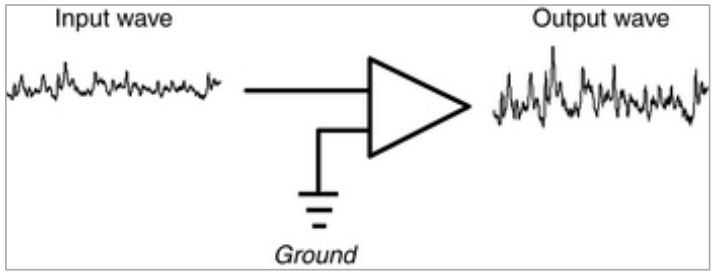
How we measure EEG?

EEG caps with electrodes

Electro-conductive Gel

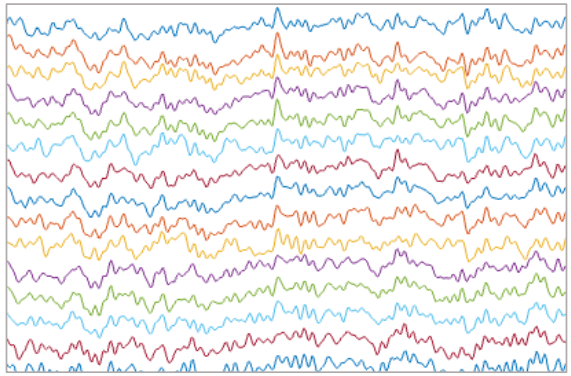


Amplifiers

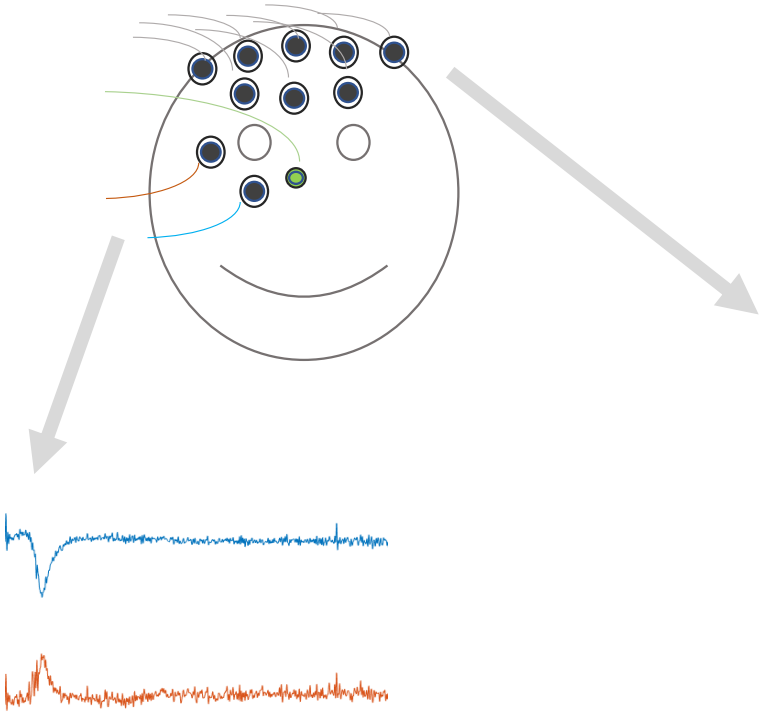


https://neupsykey.com/

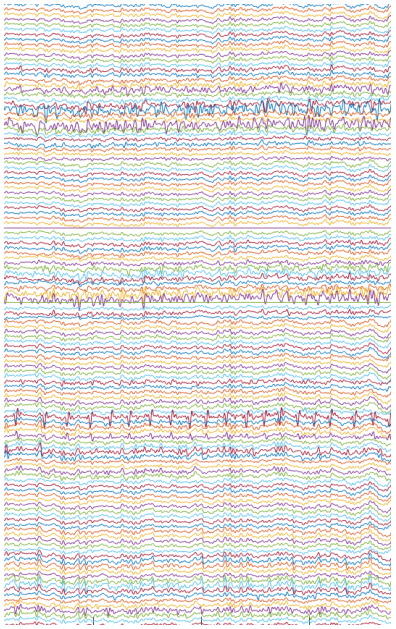
EEG Signal

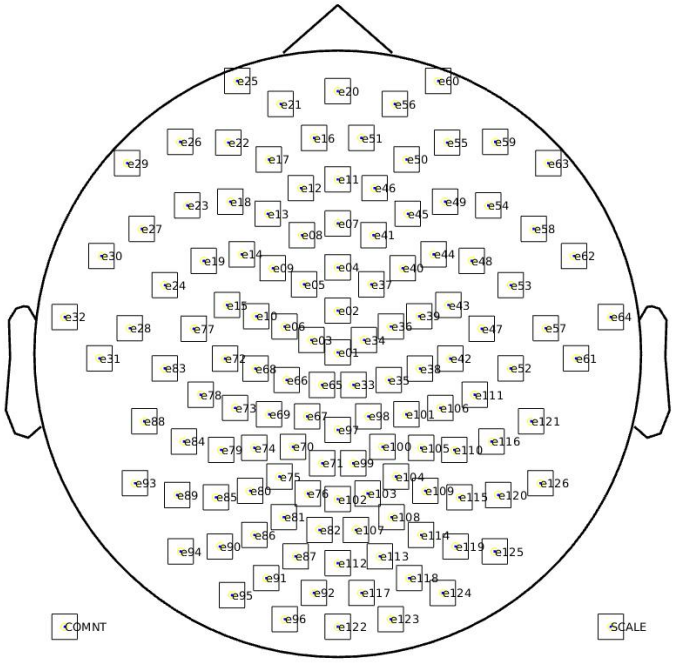


Analysis of EEG



126 electrodes , 2 EOG , 1 reference electrode





Analysis of EEG

Each recorded **sample** (time point)

	1	2	3	4	5	6	7	8	9	10	11	12
1	-9.1744	-5.6961	-4.7983	-5.7228	-6.3208	-6.4868	-7.4041	-9.3594	-11.8654	-14.4915	-16.0515	-14.3619
2	-5.8424	-3.2656	-3.5997	-5.1928	-5.6289	-5.2800	-5.9674	-8.0419	-10.4586	-12.4505	-13.4299	-12.1889
3	-5.5491	-0.8840	-0.6477	-3.5796	-5.7727	-6.1563	-6.4093	-7.6431	-9.5429	-11.5333	-12.6130	-10.9395
4	-2.8526	-0.4220	-1.2450	-3.6717	-5.0021	-5.0808	-5.4748	-6.9643	-9.2686	-11.8556	-13.4824	-12.1269
5	-4.4164	-0.4284	-0.4160	-2.8404	-4.2253	-4.0796	-4.4745	-6.5598	-9.4853	-11.8357	-12.4166	-10.3019
6	-8.2681	-2.7356	-1.2574	-3.4581	-5.6456	-6.1296	-6.1683	-7.3115	-9.7560	-12.4801	-13.5040	-10.8720
7	0.0220	1.8839	0.8914	-1.7719	-3.5884	-4.1561	-4.7955	-6.2719	-8.3072	-10.3041	-11.1894	-9.4201
8	-0.8983	1.9546	1.2250	-1.3400	-2.7698	-3.1547	-4.5516	-7.4070	-10.1665	-11.5418	-11.2330	-8.9451
9	-4.0097	1.1499	1.9375	-0.5840	-2.5538	-2.7340	-2.9587	-4.8097	-7.7836	-10.1130	-9.9910	-6.5945
10	-4.4037	2.2703	3.4066	-0.1104	-3.1334	-3.1973	-2.1369	-2.5109	-4.7361	-7.1836	-7.4323	-3.9133
11	1.0452	1.5673	0.3986	-1.5217	-2.8421	-3.7056	-4.8285	-6.1104	-7.2345	-8.4570	-9.4502	-8.3833
12	0.1077	1.6672	0.9668	-1.2106	-2.9092	-3.8064	-4.8635	-6.4273	-8.0625	-9.4186	-9.8851	-8.1461
13	-0.0741	2.6277	2.7859	1.5925	0.4624	-1.1831	-4.0739	-7.1205	-8.8108	-9.1833	-8.8177	-7.0149

.. | .. | .. | last sample

Channels (Electrodes)

..

..

128

Electrical Potential (μV) at a given electrode at a given sample

Analysis of EEG

EEG raw data: A table filled with electrical potential values (μV) corresponding to

*n*Channels (rows) X *n*Recorded Samples (columns)

Sampling rate How many samples we record per second. e.g. 1000Hz

Number of recorded samples =

1000 samples/second X 60 min experiment = 3600000 samples

Number of channels = 128

=> EEG raw data is a table of 128 x 3600000 values

Analysis of EEG

Preprocessing of raw data

Create trials of interest

Downsample

Filtering

Artifact rejection

Re-referencing

Interpolate bad electrodes

Analysis of clean data

Level: Single Subject

Event-Related Potentials (ERP)

Time-Frequency Analysis

...

Level: Group

Repeat for all subjects

Average across subjects

Statistical Evaluation

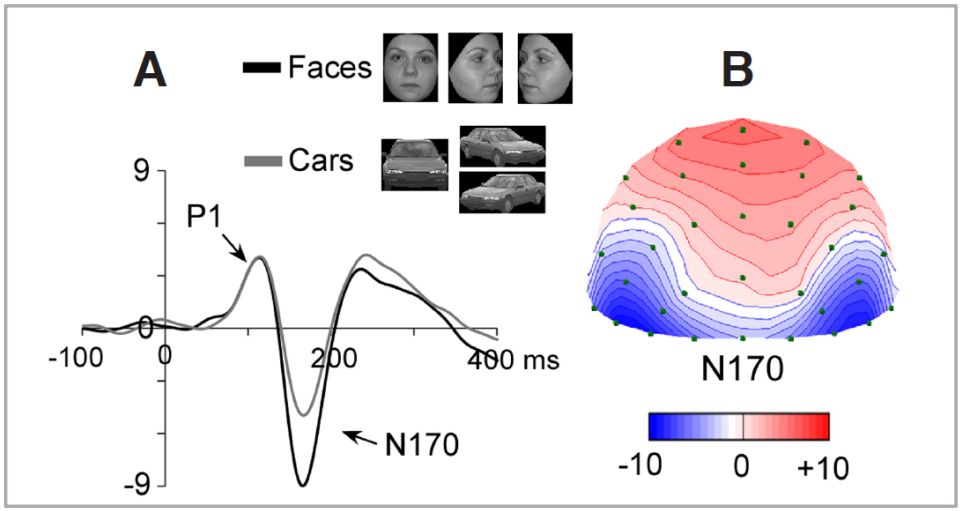
Multiple-Comparison Problem

Cluster-based statistics

...

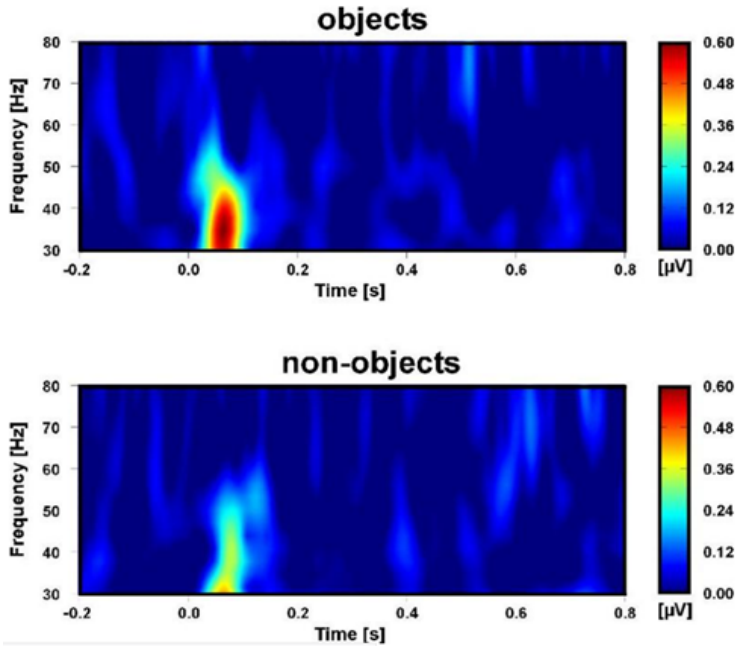
Analysis of EEG

Event-Related Potentials (ERP)



Rossion and Jacques, 2011, *The Oxford handbook of ERP components*

Time-Frequency Analysis



Herrmann et al., 2004, Neuroscience