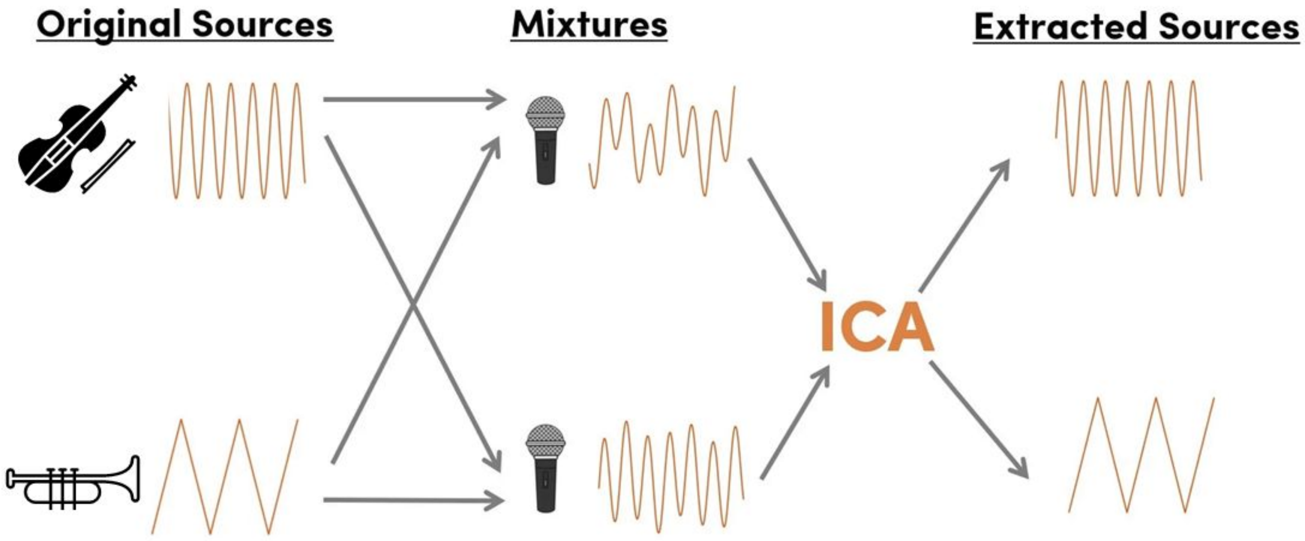
Independent Component Analysis

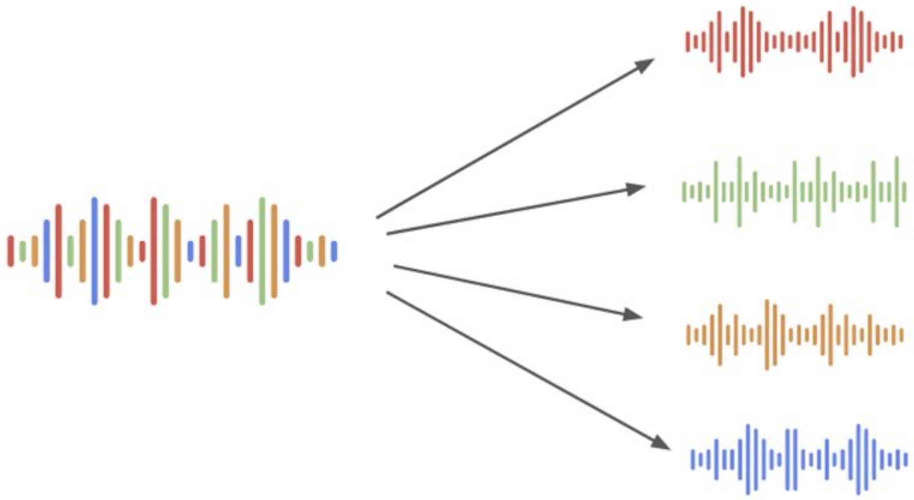
What the hell is this?

Identifying independent components – How?



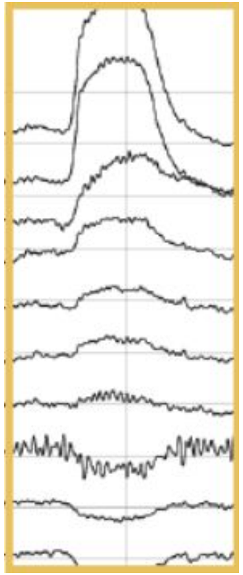
Definition

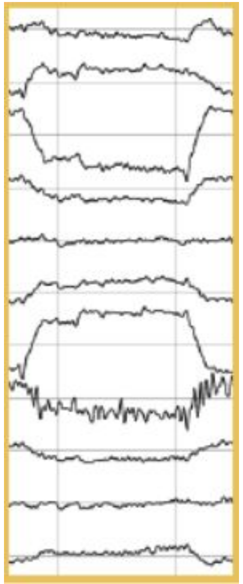
- A technique used in signal processing to extract independent sources that are **linearly combined** across multiple sensors

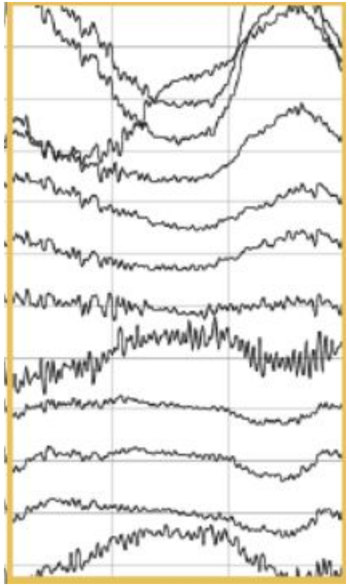


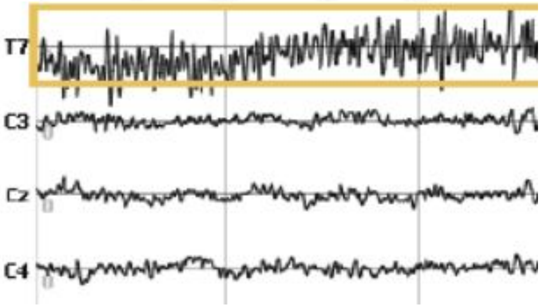
How does this apply with EEG?

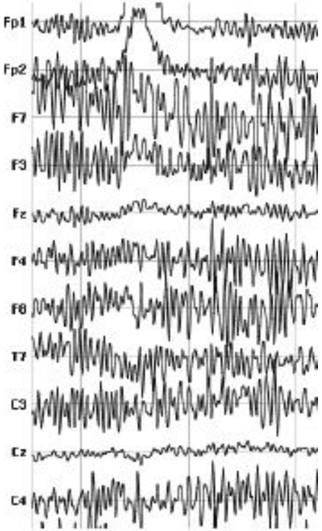
- EEG → Multiple signals combined → **problem**
- ICA → untangle original signals
  - Separate artifacts embedded in the data
  - Artifacts *usually* independent of each other

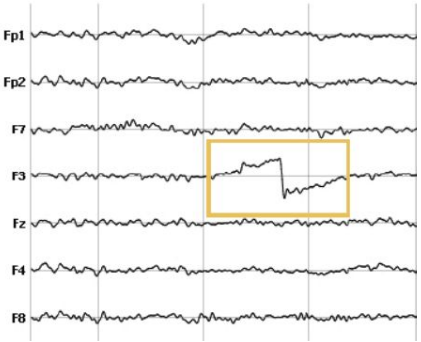








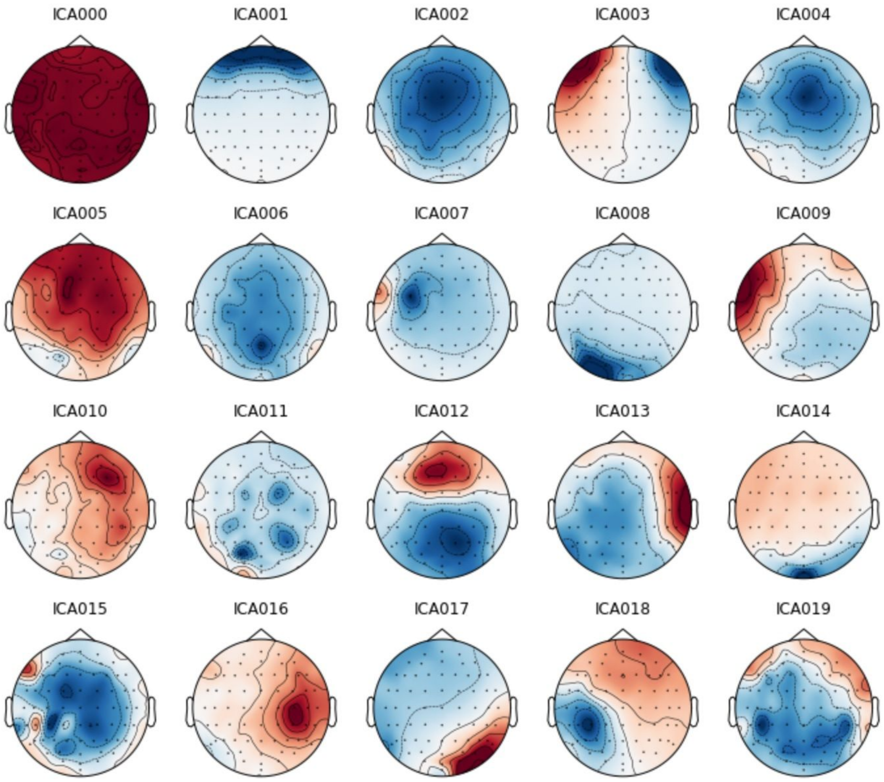


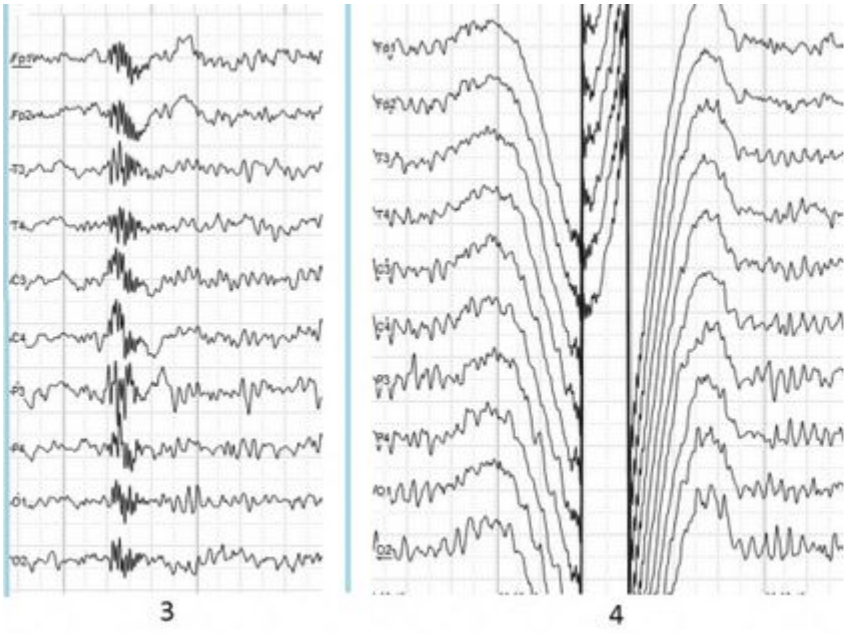


Independent Components in EEG

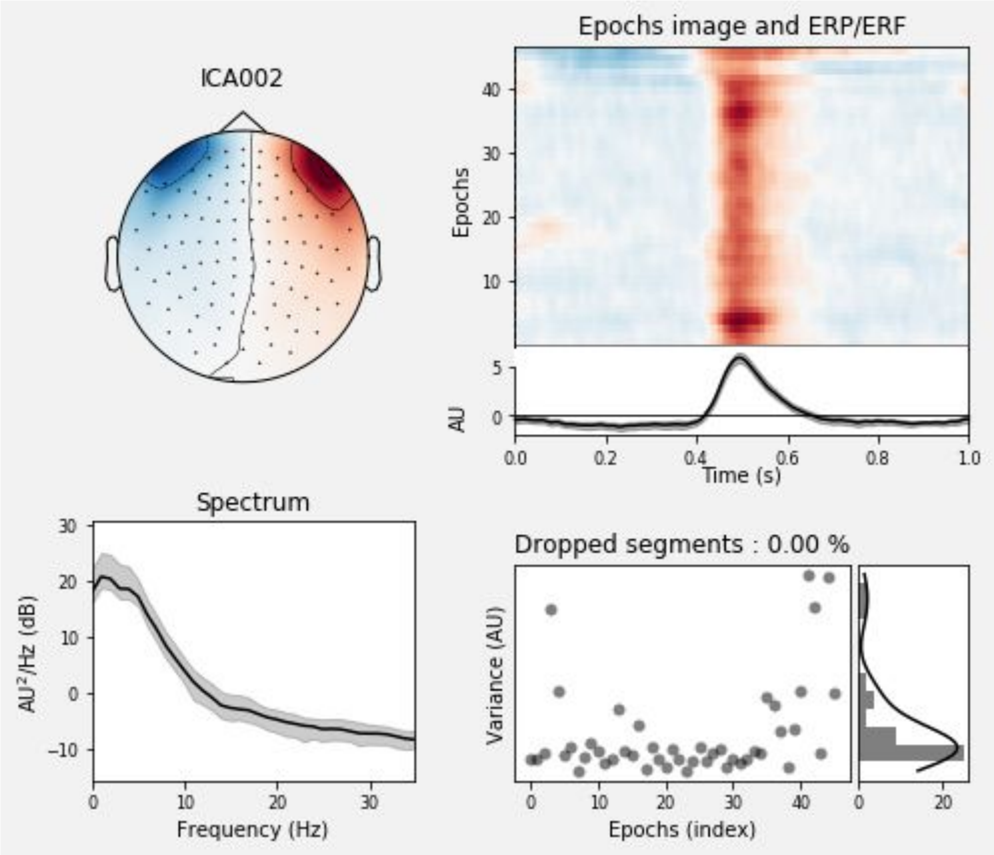
```
eeg_ica = eeg.copy()
ica = mne.preprocessing.ICA(n_components=0.99,
method='fastica', random_state=99)
ica.fit(eeg_ica)

ica.plot_components()
```



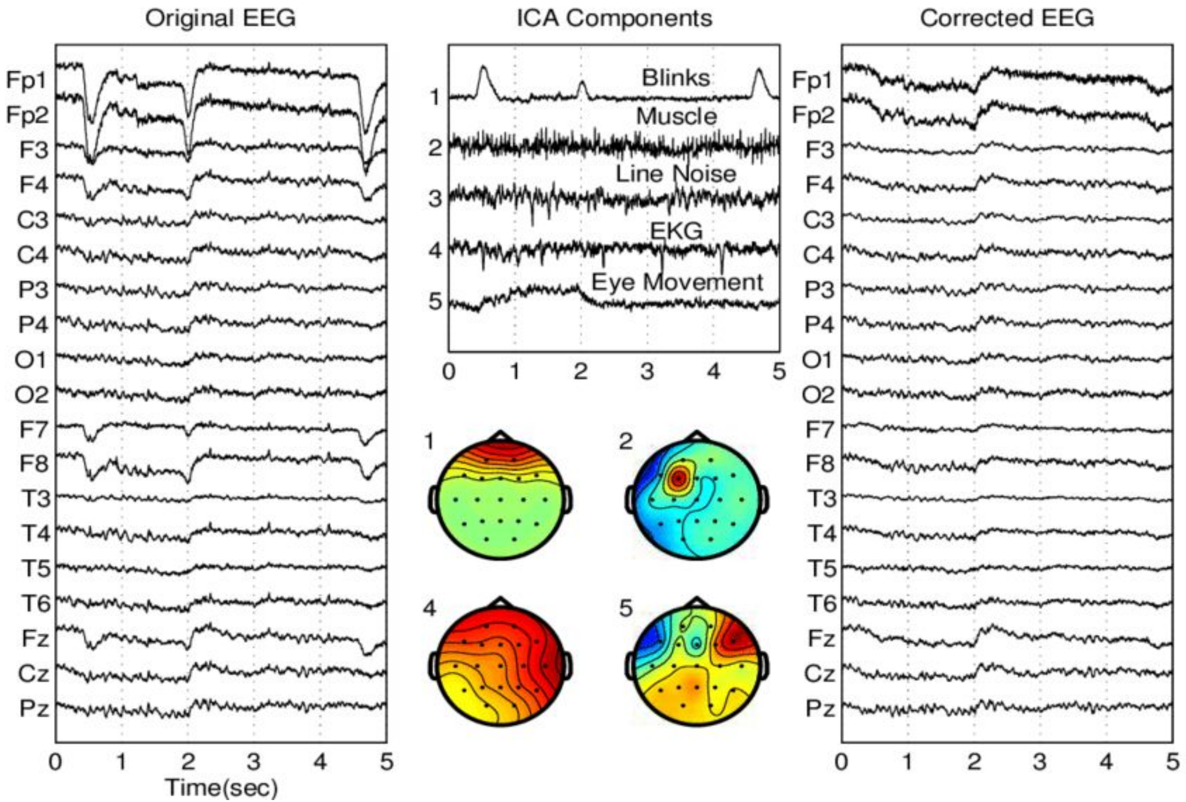


mne.Epochs(eeg, reject_by_annotation=True)


ICA002
Epochs image and ERP/ERF
Epochs
AU
Time (s)
Spectrum
AU²/Hz (dB)
Frequency (Hz)
Dropped segments : 0.00 %
Variance (AU)
Epochs (index)

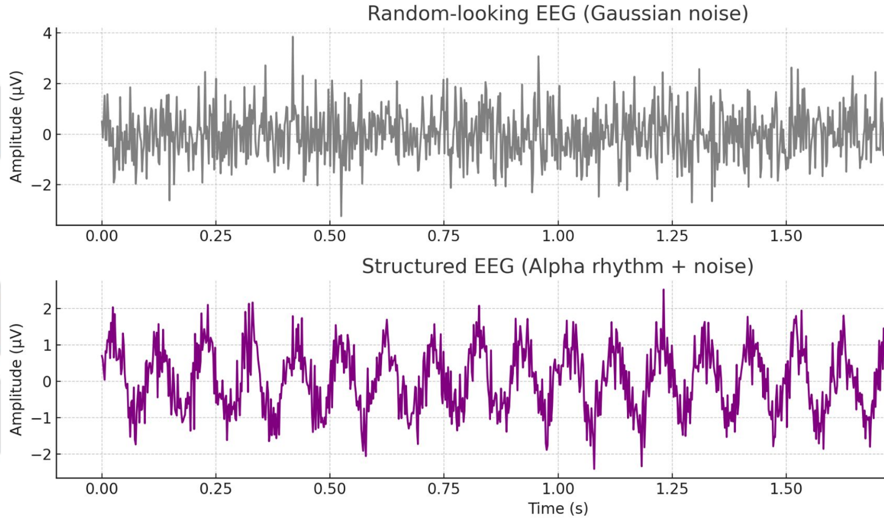
Independent Components in EEG

```
ica.plot_sources(eeg_ica)
ica.apply_ica(eeg_ica)
```



The three main characteristics of ICA

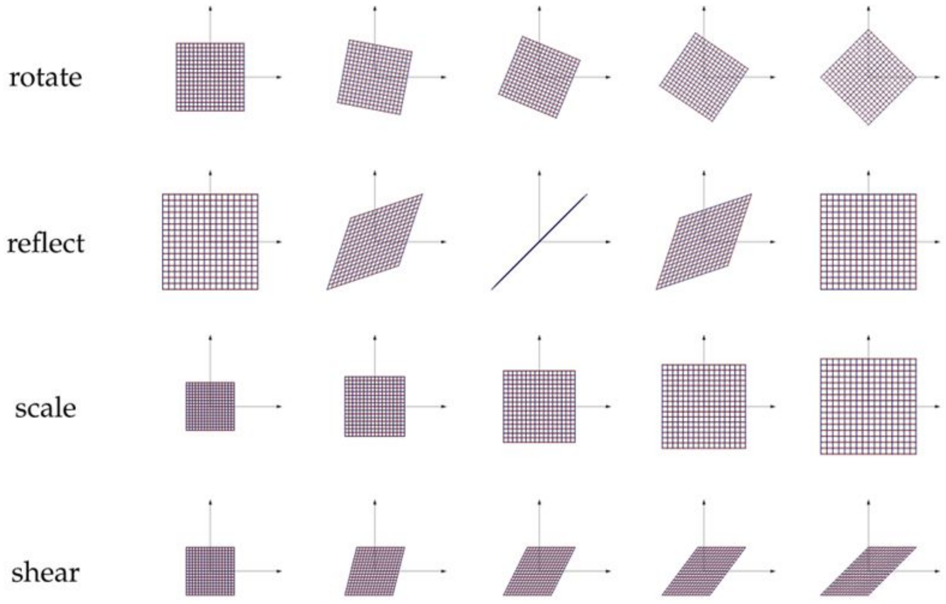
- **Source Separation** → distinguish and isolate independent sources from a mixed signal
- **Independence** → each signal component occurs independently → **they do not influence each other**
- **Non-Gaussian** → sudden and unpredictable, rare event
  - Data distribution **does not** follow the normal **bell-shaped curve**
  - Irregularity in EEG signals



ICA steps: *it is all about matrix transformations!*

- **EEG Data→** amplitude changes over time, across all 64 electrodes → a matrix
- **Pre-processing:**
  - Centering
  - Data whitening (equalizing signal importance)
- **Applying ICA:**
  - Component extraction
  - Component selection
- Reconstruction of signal (blending the components)

Essence of linear algebra by 3Blue1Brown



Applying ICA

$$X = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix}$$

$$W = \begin{bmatrix} 0.5 & 0.3 & 0.2 \\ 0.1 & 0.7 & 0.4 \\ 0.4 & 0.6 & 0.8 \end{bmatrix}$$

- PCA to identify spatial patterns
- Linear decomposition of signal
- Maximization of independence → using a demixing matrix
- Component identification
  - Non Gaussian
  - Each component has its own
- Reconstruction of signal

$$\begin{pmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{pmatrix} \cdot \begin{pmatrix} 0.5 & 0.3 & 0.2 \\ 0.1 & 0.7 & 0.4 \\ 0.4 & 0.6 & 0.8 \end{pmatrix} = \begin{pmatrix} \frac{19}{10} & \frac{7}{2} & \frac{17}{5} \\ \frac{49}{10} & \frac{83}{10} & \frac{38}{5} \\ \frac{79}{10} & \frac{131}{10} & \frac{59}{5} \end{pmatrix}$$

```
ica = mne.preprocessing.ICA(n_components=0.99, method='fastica', random_state=99)
```