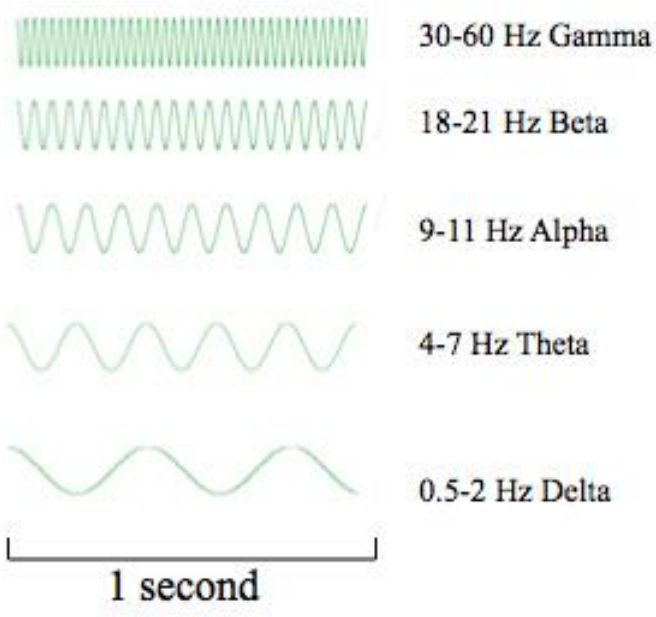
So your data is clean, now what?
2. Spectral Analysis

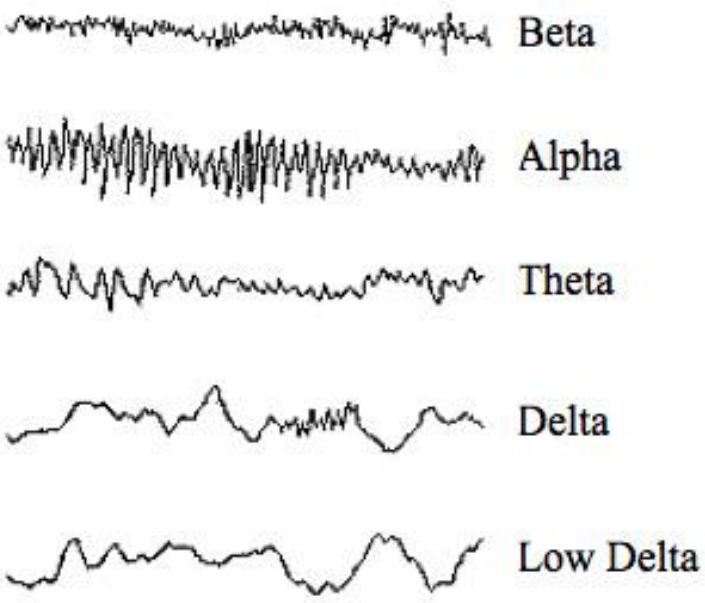
Sabrina Sghirripa

Neural Oscillations

Imagine how easy life would be if EEG looked like this:

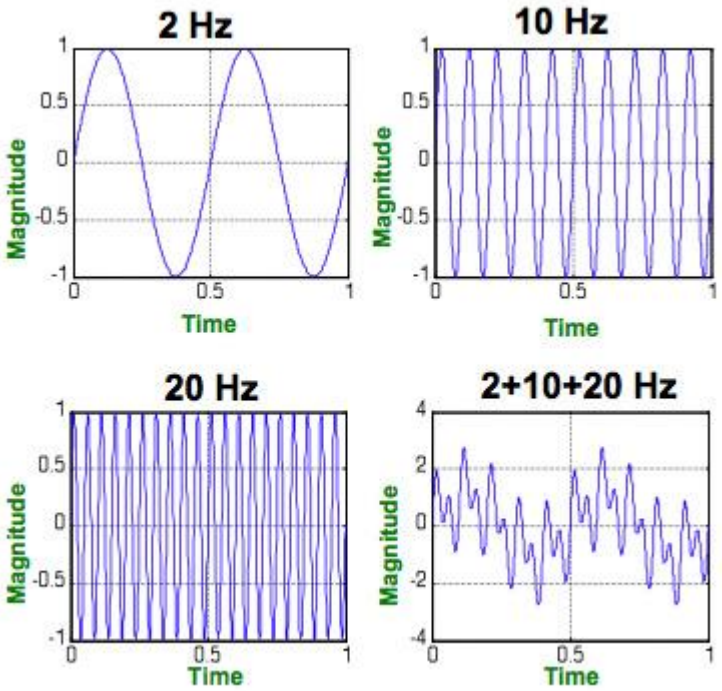


Instead, we have this:



Spectral Decomposition

- EEG data is a mixture of different frequencies
- Complex signal
- How do we go from the time domain to the frequency domain?

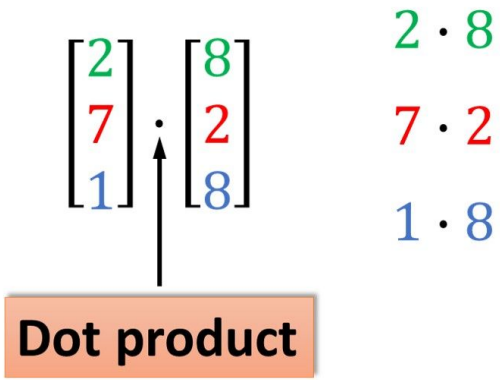


Time Domain

Some mathematical terms

- Dot product → A single number computed based on two vectors of equal length
    - Multiply each element in one vector by the corresponding element of the other vector (element 1 in A, by element 1 in B, so on), then sum all of the points together

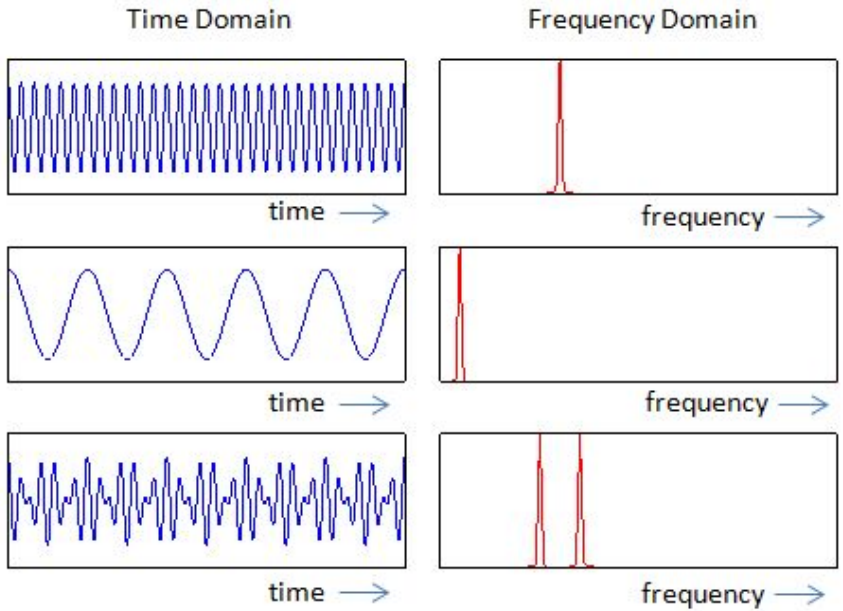
- Convolution → In the time domain, convolution is an extension of the dot product in which the dot product is computed repeatedly over time
    - A time series of one signal weight by another signal (called a kernel) which slides across the first signal



Convolution

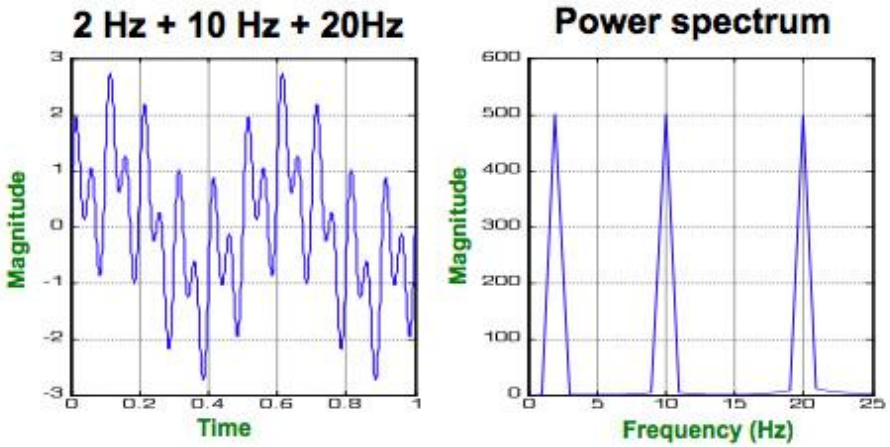
Fourier Transform

- Backbone of most EEG analyses
- Works by computing the dot product between the signal (EEG) and kernel (sine wave of different frequencies)
    - Sine waves have 3 characteristics: power (amplitude squared), frequency (speed in Hz), phase (timing of sine wave measured in deg or radians)

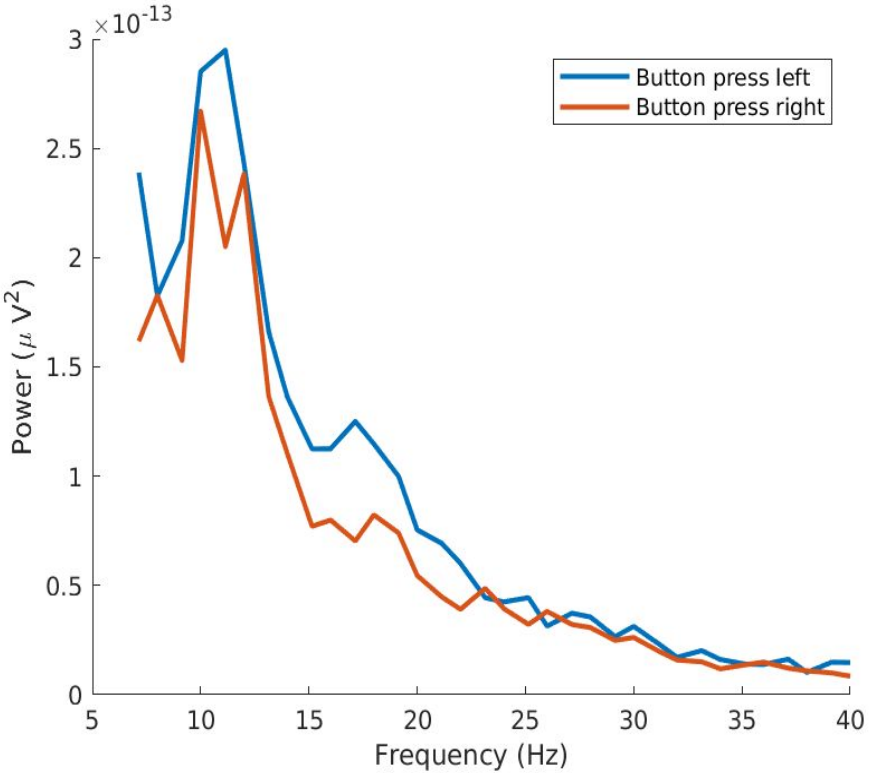


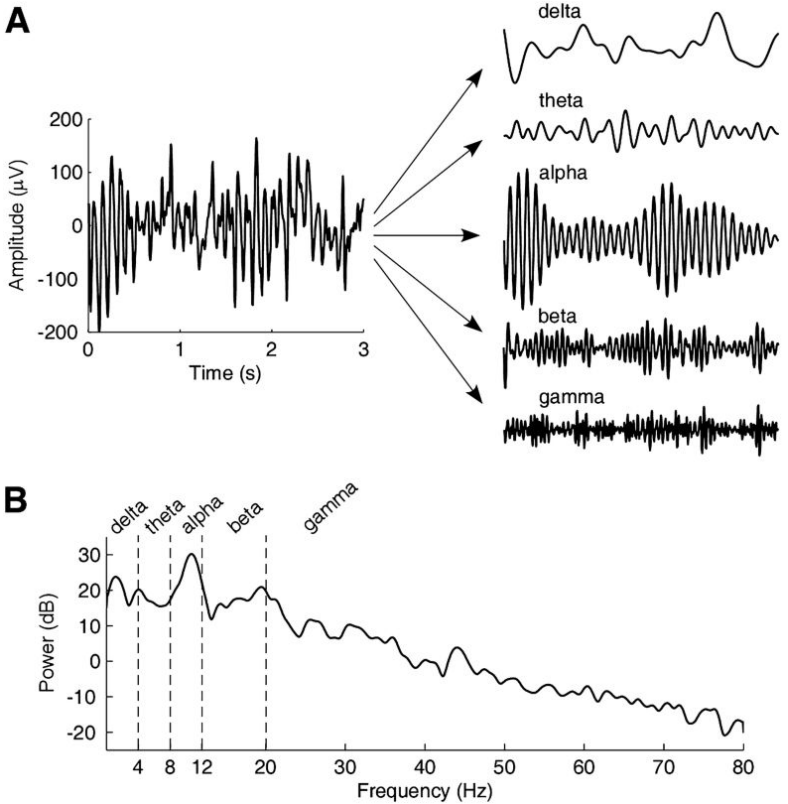
Fourier Transform

- Running a Fourier Transform on the clean, idyllic data in the earlier slide:



Power Spectral Density



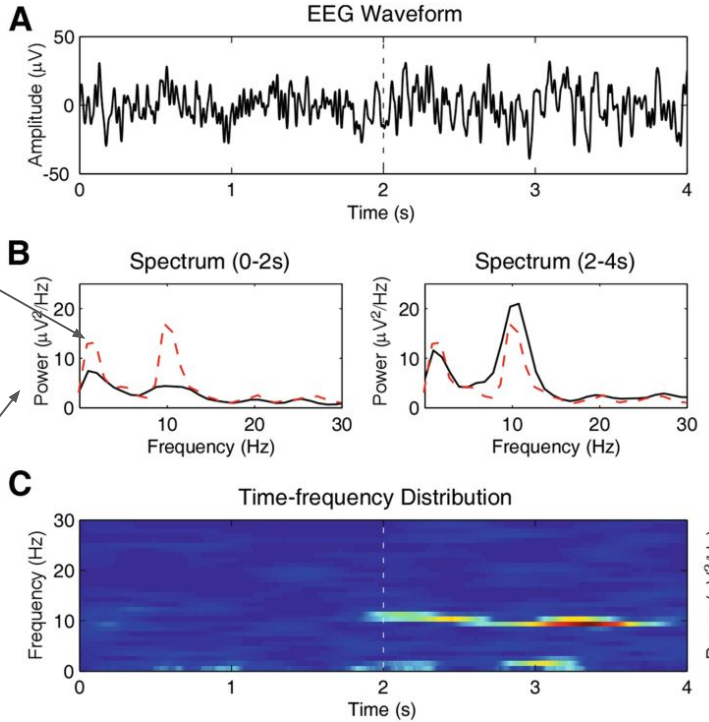


Zhang (2019) *EEG Signal Processing and Feature Extraction* pp 86-116

But there are some issues here...

- Stationarity is an assumption of the Fourier transform
  - Stationarity = mean, variance, frequency of signal do not change over time
  - Obviously, EEG constantly violates this
  - Characteristics of EEG vary with time
    - Physiological states?
    - Cognitive states?

Red dashed lines = spectrum of the whole signal

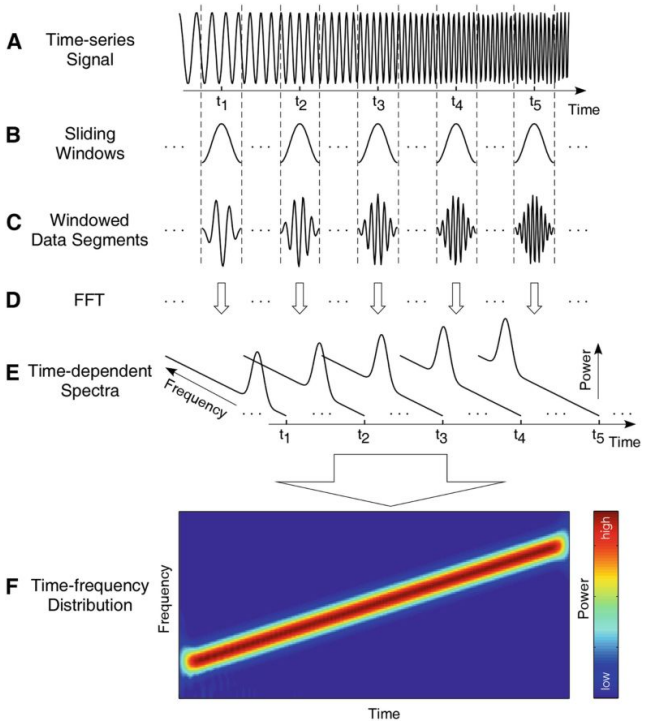


No time information!

Zhang (2019) *EEG Signal Processing and Feature Extraction* pp 86-116

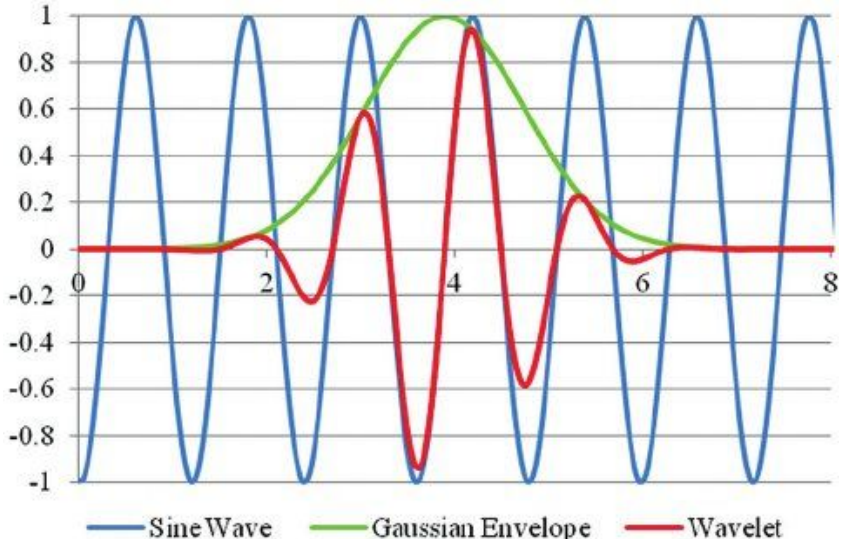
Time Frequency Analysis

Short-Time Fourier Transform

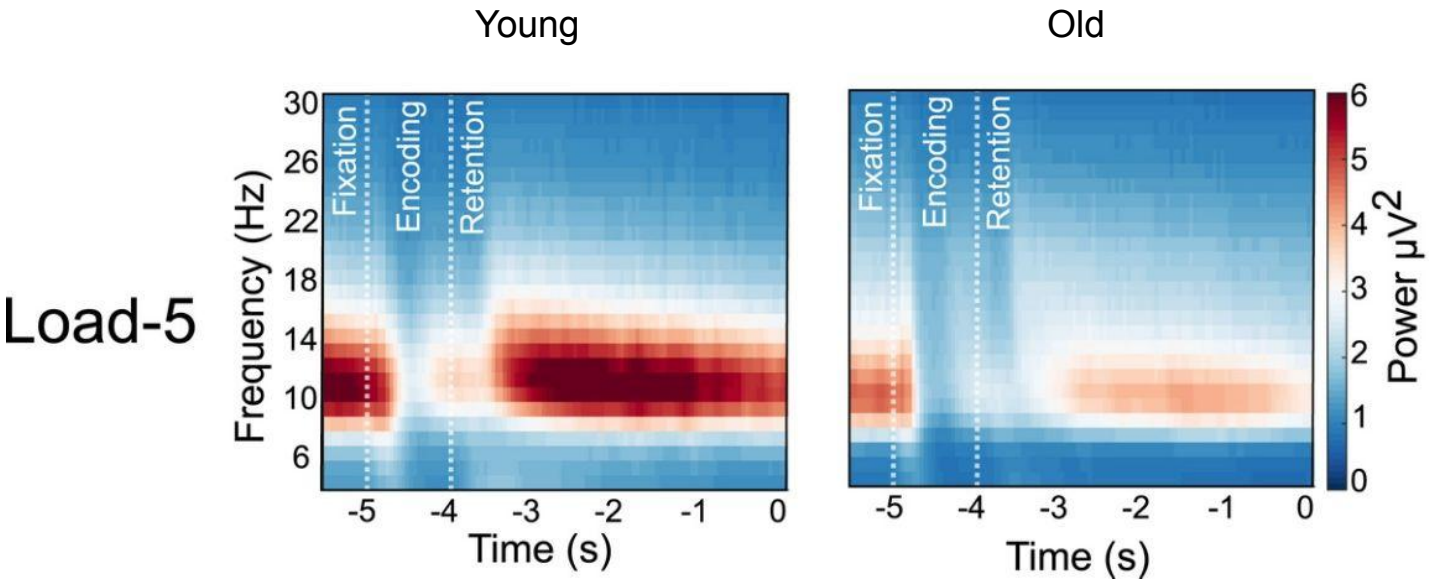


Wavelets

- Take a sine wave and multiply it by a Gaussian
- Convolve the wavelet with the EEG signal by sliding it across

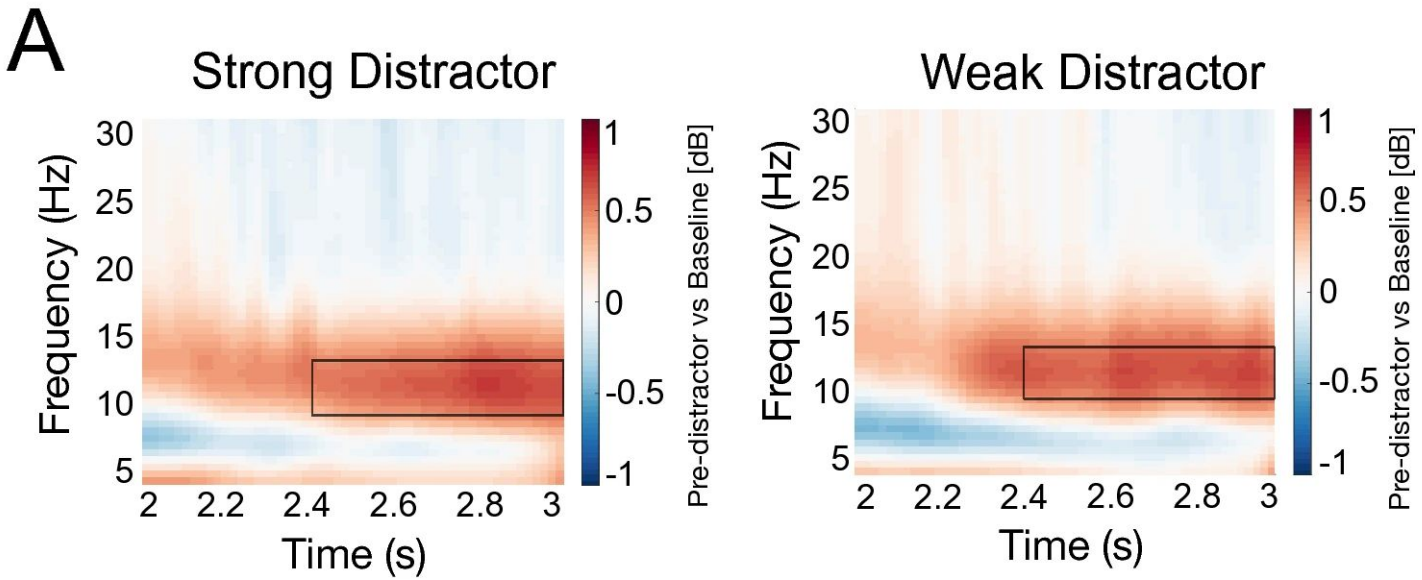


Time Frequency Representation (no baseline correction)



Sghirripa et al. (2020)
Psychophysiology

Time Frequency Representation (with baseline correction)



Sghirripa et al. (2020)
Brain Topography