NeuroAI Lab

EPFL

INTRODUCTION TO EEG BCI APPLICATIONS AND VISUALIZATION

EPFL

Tutorial Materials

Scan the QR code:

Or visit:

github.com/akgokce/eeg_tutorial

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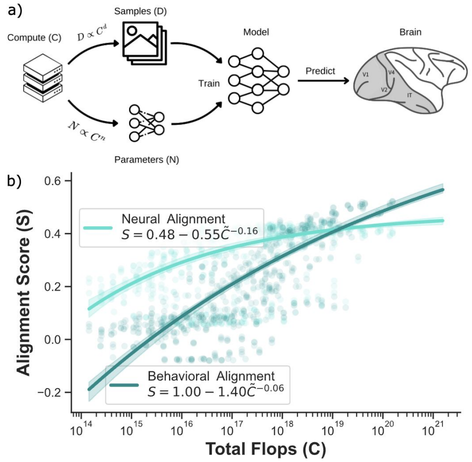
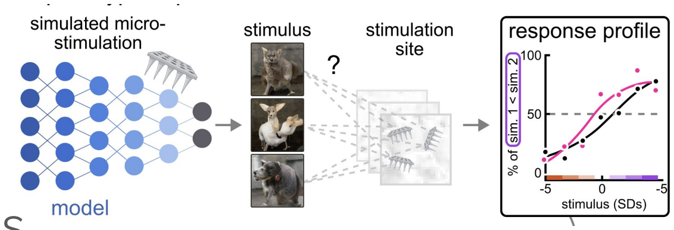
NeuroAI Lab

- A joint lab between SV and IC
- We build computational models for understanding of the neural mechanisms underlying human natural intelligence.
- We investigate model-brain alignment across a variety of modalities to guide our efforts in building SOTA brain models.
- Courses: BIOENG-310, NX-414, student projects

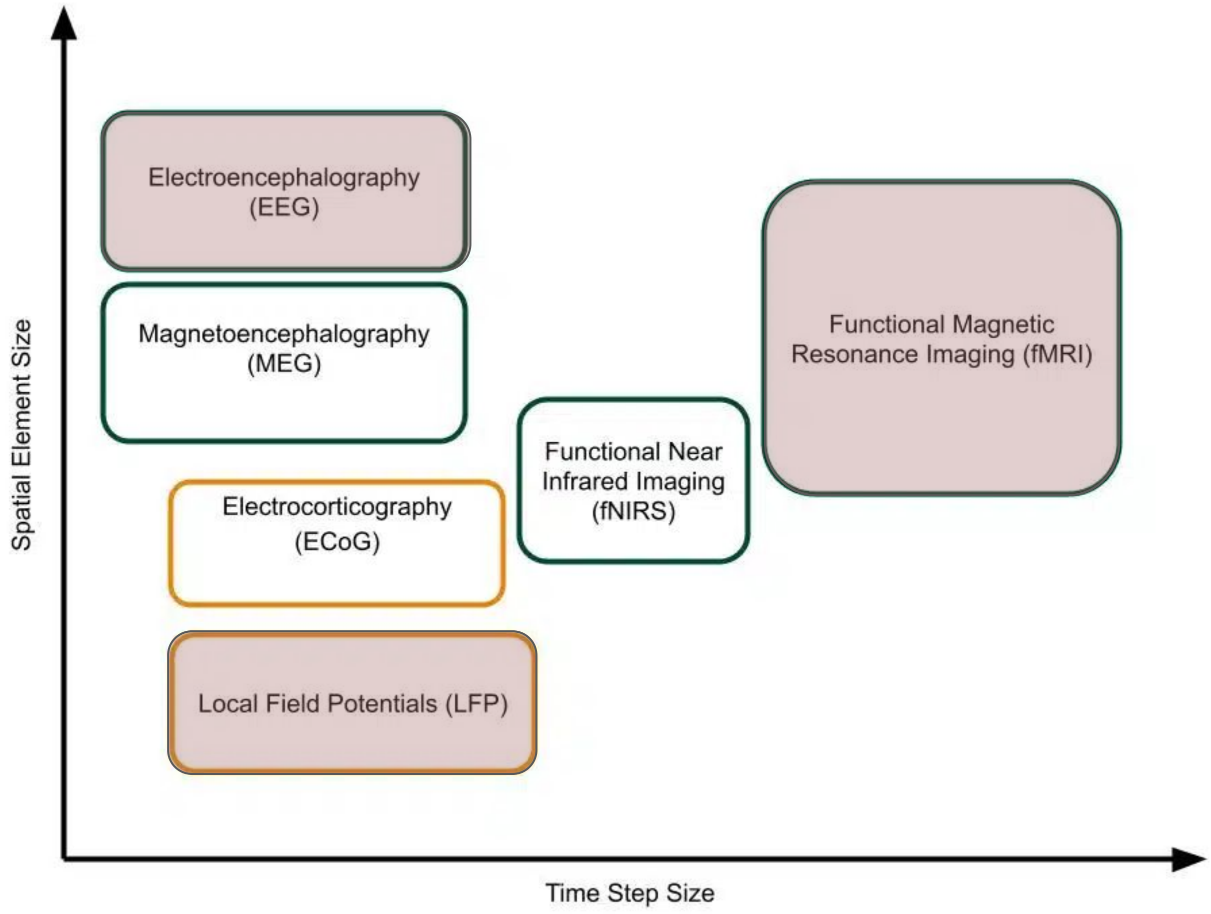


Gokce et. al. 2025



Mehrer et. al. 2025

Brain Recording Modalities



Credit: BrainAcceess

Getting Started with EEG

What is Electroencephalography?

- Measures the electrical activity of the brain
- Non-invasive: electrodes placed on the surface of the scalp
- Advantages:
  - High temporal resolution
  - Easy setup
  - Cheap
- Disadvantages:
  - Low signal-to-noise ratio
  - Low spatial resolution
  - High variability

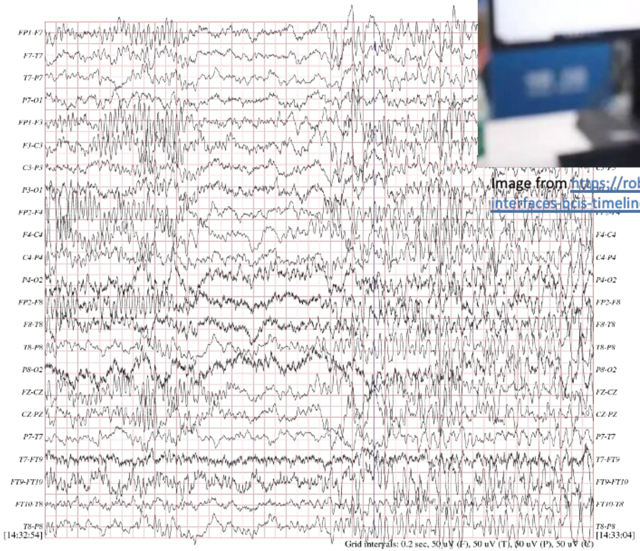
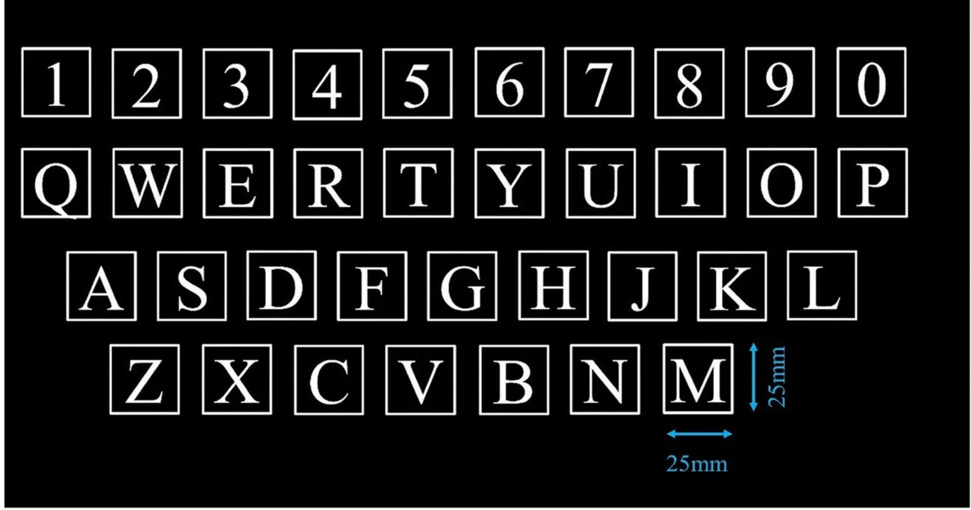
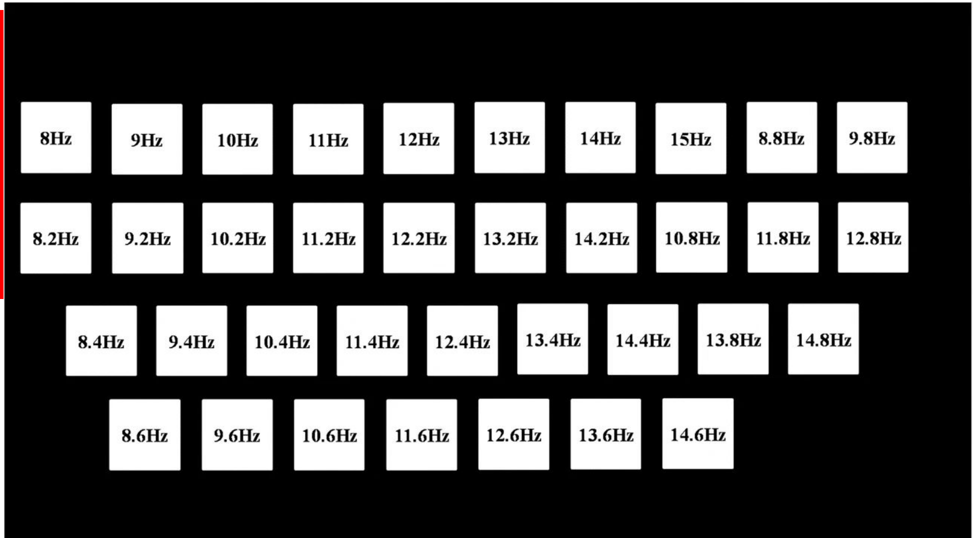


Image from https://roboticsbiz.com/the-history-of-brain-computer-interfaces-bcis-timeline/

SSVEP Speller Example



(a)



What is SSVEP

- SSVEP: Steady-State Visually Evoked Potential
- Oscillatory EEG response elicited when a person looks at a flickering visual stimulus.
- Better observed in the frequency or time–frequency domains.

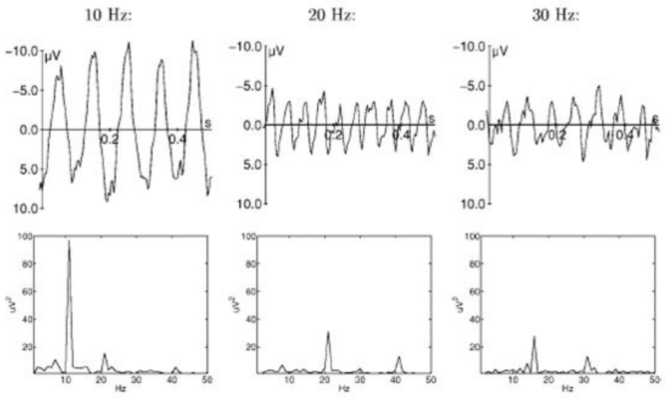
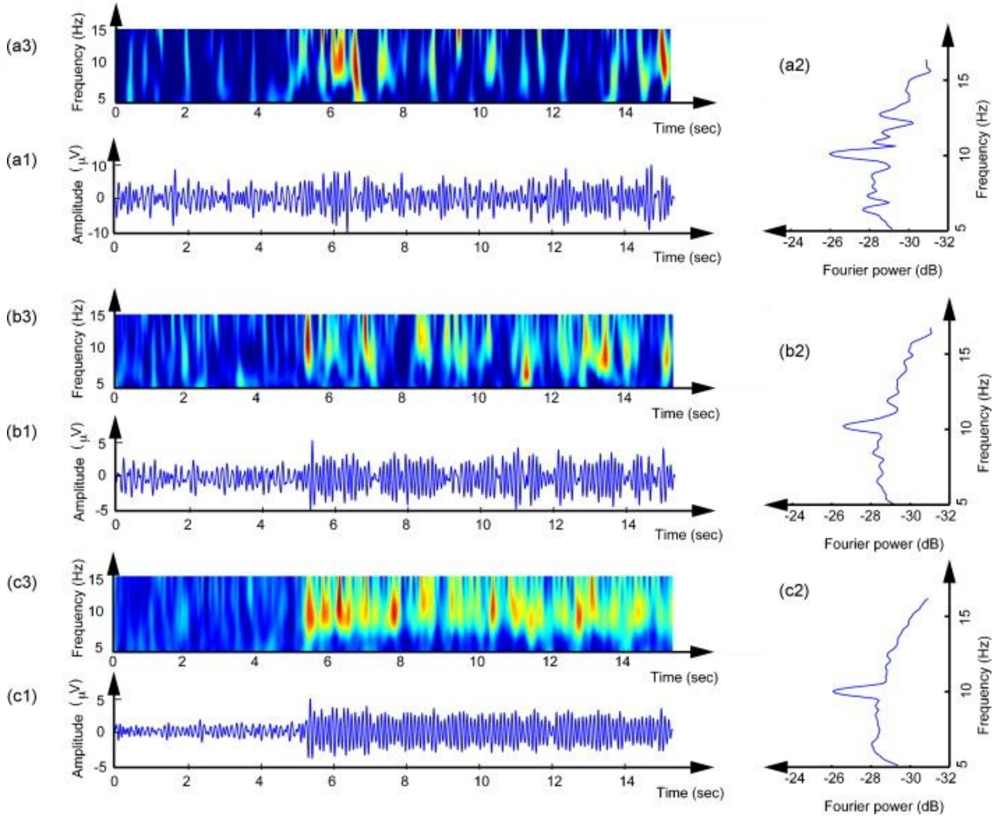


Figure from Herrmann et al. (2001)

SSVEP Characteristics

- Fixed latencies, automatic response to the stimulus
- Stable frequency components (constant amplitude & phase)
- Less susceptible to artefacts
- High SNR: can be extracted even from single trials



(a) single trial, (b) 10-trial average, (c) 20-trial average.
Figure from Vialatte et al. (2010).

Example: A Virtual Keypad

- Data preparation and visualization
- Decoding the 12 targets from EEG responses
    - Canonical correlation analysis (CCA)
    - EEGNet (a convolutional deep neural network)

[Colab Notebook]

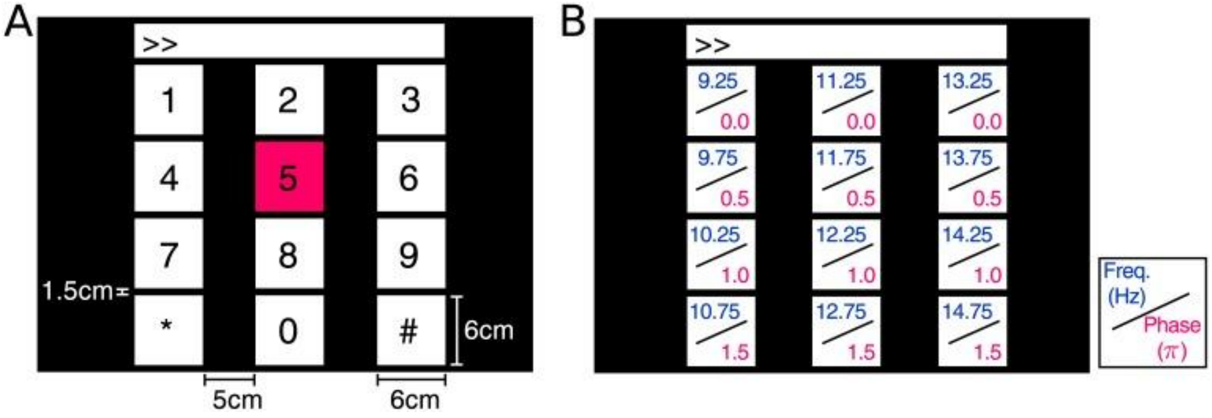
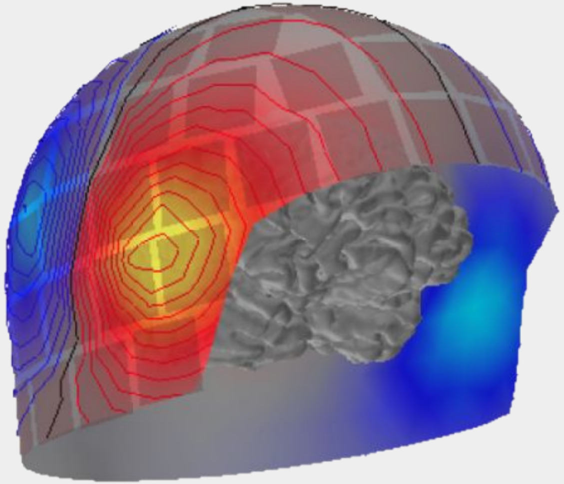


Figure from Nakanishi et al. (2015).

Introduction to MNE Package

MNE

MEG + EEG ANALYSIS & VISUALIZATION



MNE Python

- Python package for analyzing human neurophysiological data
  - MEG, EEG, ECoG
- Load different data formats
- Signal processing pipelines
- Encoding and decoding
- Visualization

[Link to the website]()

frontiers in NEUROSCIENCE

METHODS ARTICLE
published: 26 December 2013
doi: 10.3389/fnins.2013.00267

MEG and EEG data analysis with MNE-Python

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Magnetoencephalography and electroencephalography (M/EEG) measure the weak electromagnetic signals generated by neuronal activity in the brain. Using these signals to characterize and locate neural activation in the brain is a challenge that requires expertise in physics, signal processing, statistics, and numerical methods. As part of the MNE software suite, MNE-Python is an open-source software package that addresses this challenge by providing state-of-the-art algorithms implemented in Python that cover multiple methods of data preprocessing, source localization, statistical analysis, and estimation of functional connectivity between distributed brain regions. All algorithms and utility functions are implemented in a consistent manner with well-documented interfaces, enabling users to create M/EEG data analysis pipelines by writing Python scripts. Moreover, MNE-Python is tightly integrated with the core Python libraries for scientific comptutation (NumPy, SciPy) and visualization (matplotlib and Mayavi), as well as the greater neuroimaging ecosystem in Python via the Nibabel package. The code is provided under the new BSD license allowing code reuse, even in commercial products. Although MNE-Python has only been under heavy development for a couple of years, it has rapidly evolved with expanded analysis capabilities and pedagogical tutorials because multiple labs have collaborated during code development to help share best practices. MNE-Python also gives easy access to preprocessed datasets, helping users to get started quickly and facilitating reproducibility of methods by other researchers. Full documentation, including dozens of examples, is available at http://martinos.org/mne.

Keywords: electroencephalography (EEG), magnetoencephalography (MEG), neuroimaging, software, python, open-source