Attention and Consciousness Research Group

Machine Learning approaches to investigate neurophysiological markers in language and perceptual tasks

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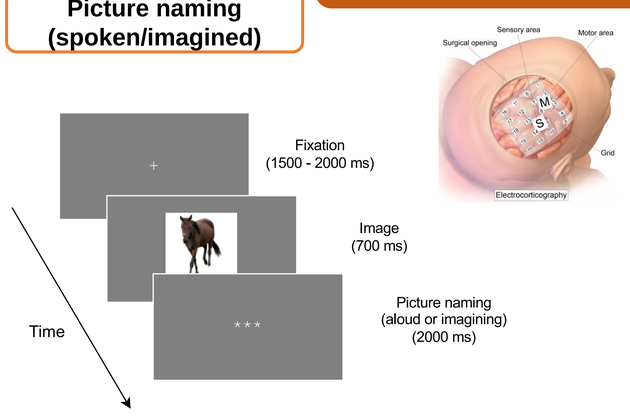
Aims and objectives

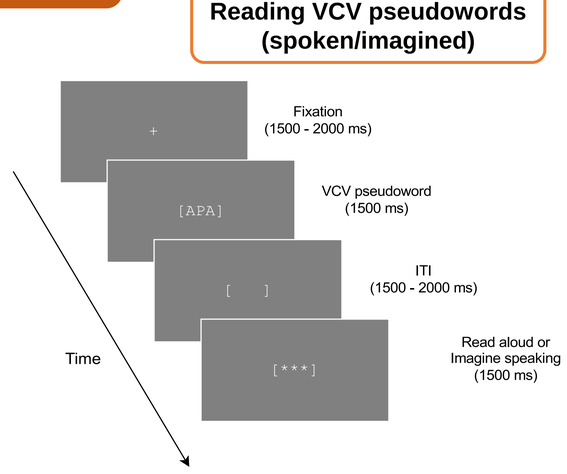
- Application of ML techniques to decode two different cognitive processes from neuroimaging (EEG) data: **perception** and **speech production**
- **Speech production:** identify brain regions involved in language processing, develop Brain-Computer Interfaces.
- **Perception:** decode participants' responses to conscious detection and discrimination tasks, with the final aim of detecting errors.

Speech production

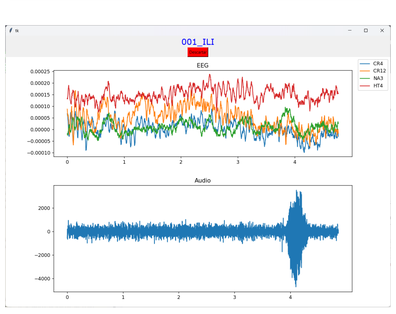
Picture naming (spoken/imagined)

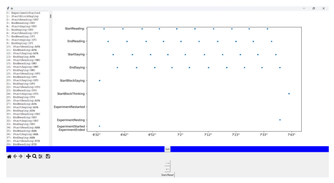


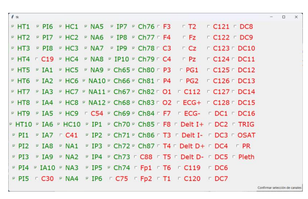
Reading VCV pseudowords (spoken/imagined)



Preprocessing







- ➔ EEG and audio recorded on different devices
- ➔ Aligning EEG with audio required finding the starting point of the experiment
- ➔ High gamma features extracted from raw EEG
- ➔ Graphical interface to choose required channels and flag trials as good or bad

Methods

Tasks

- Vowel and consonant classification
- Picture category clasiification
- EEG to speech synthesis
- EEG differences in speech vs imagine conditions

Features

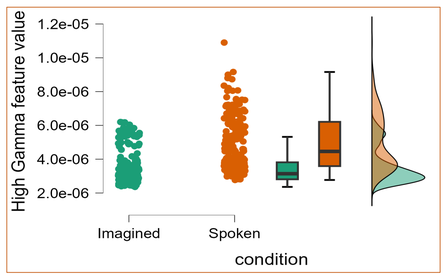
- High gamma EEG features
- Mel Cepstral audio features
- WORLD vocoder audio features
- One-hot encoded vowel, consonant and picture categories

Algorithms

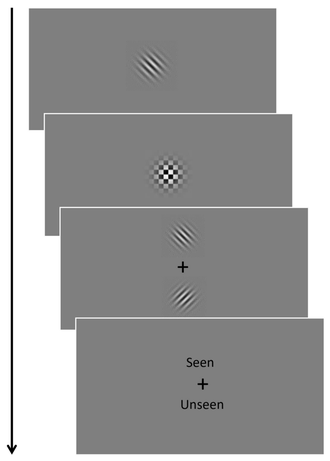
- Linear regression
- Deep Neural Networks
- Convolutional Neural Networks
- Statistical differences

Results

- ➔ Significant differences were observed in EEG features in the Spoken and Imagined conditions
- ➔ Picture category classification had better than chance results (30 percent accuracy), but not high enough.
- ➔ Vowel and consonant classification results were not better than chance.
- ➔ Speech decoding results were unsatisfactory.



Perception decoding



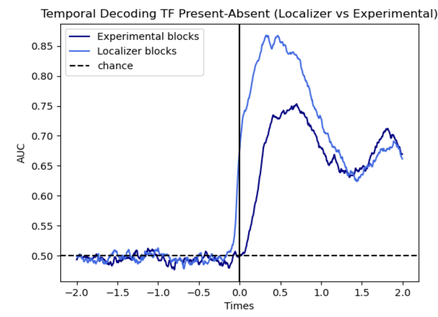
Task procedure (simplified)

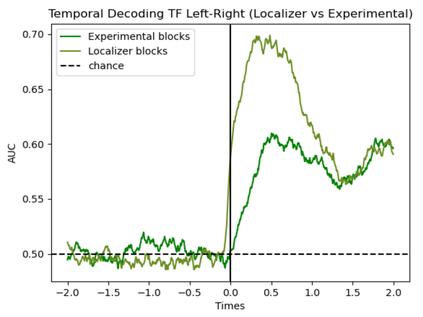
Methods

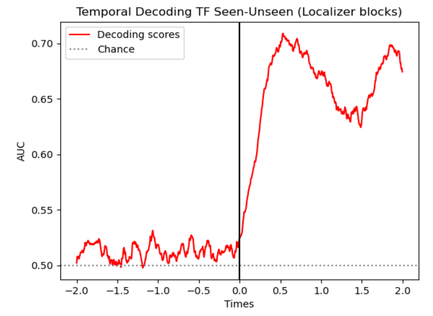
- ➔ 64 high-density EEG cap = 30
- ➔ 3 types of blocks:
  1. Titration: calibrate for ~50% seen stimuli
  2. Localizer (5 blocks): supra-threshold contrast
  3. Experimental (10 blocks): near-threshold contrast

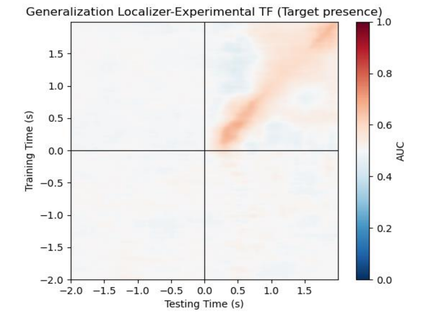
  } 900 trials
- ➔ Decoding across time
- ➔ Generalization analyses
- ➔ Free and open-source code: Python, MNE, scikit-learn…

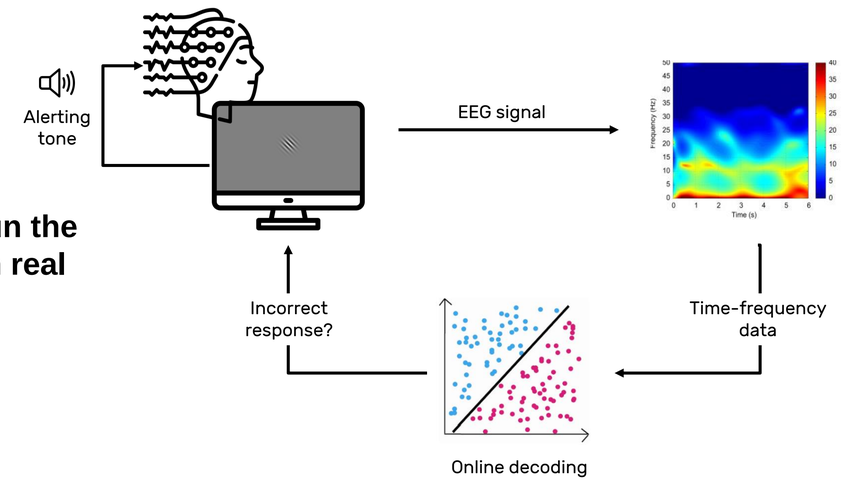
Preliminary decoding results











Next step: run the analyses on real time!

Outcomes and future work

- There were **differences** in the distributions of high gamma features in the **brain activity** when the participant **spoke vs imagined** words. Next steps would be to find out electrodes with the most effects, and repeat the experiment for the picture naming task
- **Picture category classification** showed **30% accuracy**, speech decoding algorithms need improvement by way of electrode choice, algorithms focused at EEG data and trying other ways of preprocessing and feature extraction.
- **Perception decoding:** we can decode task-relevant features (target presence, awareness, stimulus orientation), and decoding accuracy seems to be higher at 4-30 Hz. We are now working on being able to do this before target onset, to detect (and hopefully, prevent) errors.
- It would be interesting to see if we can generalize the classification between participants and try to select a subset of channels that provide the maximum amount of information to the classifier. This could help reduce computational load and make the analyses faster.

This work has been supported by the FEDER/Junta de Andalucía-Consejería de Transformación Económica, Industria, Conocimiento y Universidades (B-SEJ-570-UGR20 PIs: Ana B. Chica and Jose A. Gonzalez-Lopez) and Spanish Ministry of Science and Innovation (PID2020-119033 GB-I00, PI: Ana B. Chica)

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