Mila

Université de Montréal

Dance of the Neurons: Unraveling Sex from Brain Signals

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Introduction

- Pathology detection & Therapeutic interventions
- ✅ Advancements because of AI
- 🛑 Response of prescription drugs (Lee [2018])
- 🛑 Characteristic of disorders
  - Dementia (Podcasyand Epperson [2016])
  - Autism (Williams et al. [2021])
- 👩‍🎓🥼 Structural vs Functional
  - Structural diff. are minor (Eliot et al. [2021])
- Detectability | Generalization
- Impact on Pathology?
  - Imbalanced data
  - Important pattern

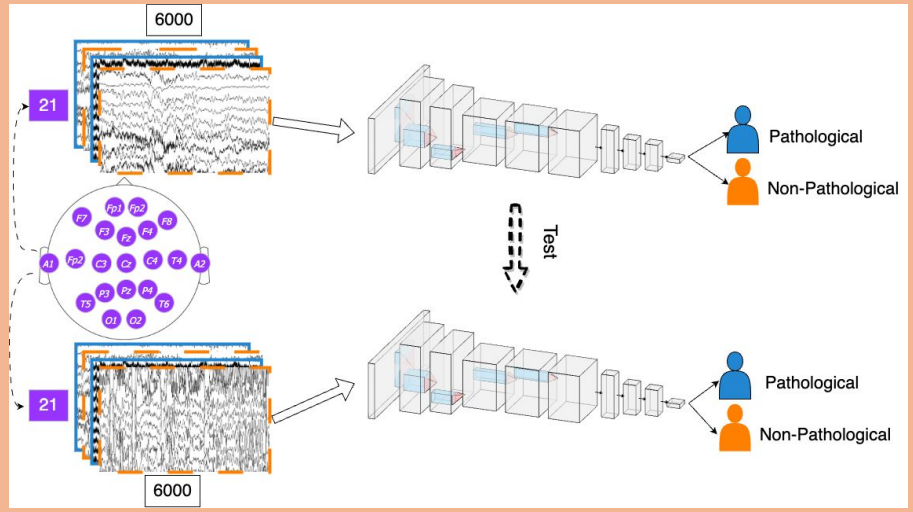
Datasets

Study	# of Participants	# of Recordings	Conditions	Dataset
Van Putten et al. [2018]	1308 (1000, 308)	1308	All Non-Pathological	In Lab
Bučková et al. [2020]	144	144	MDD	In Lab
Jochmann et al. [2023]	1282 (1140, 142)	1282	Only Non-Pathological Split	TUAB
Ours	2417	2417	Non-Pathological/Pathological	Public-NMT
Ours	2329	2978	Non-Pathological/Pathological	Public-TUAB
Ours	14987	69000	Unlabeled	Public-TUEG

Table 1. A comparison of previous studies on EEG sex detection. The table shows the name of the study, the dataset used, the number of participants and recordings in the dataset and in (train, test) splits, participants' conditions, and the data availability.

- **TUEG (Temple University Hospital EEG Corpus)** (Obeid and Picone [2016])
  - This extensive open-source EEG data corpus
  - Demographic information (sex and age)
- **TUAB (Temple University Hospital Abnormal EEG Corpus)** (Shawki et al. [2022])
  - A subset of the TUEG corpus
  - Normal or Abnormal
  - Demographic information (sex and age)
- **NMT (NUST-MH-TUKL EEG)** (Khan et al. [2022])
  - Normal or Abnormal.
  - Demographic information (sex and age)

Method

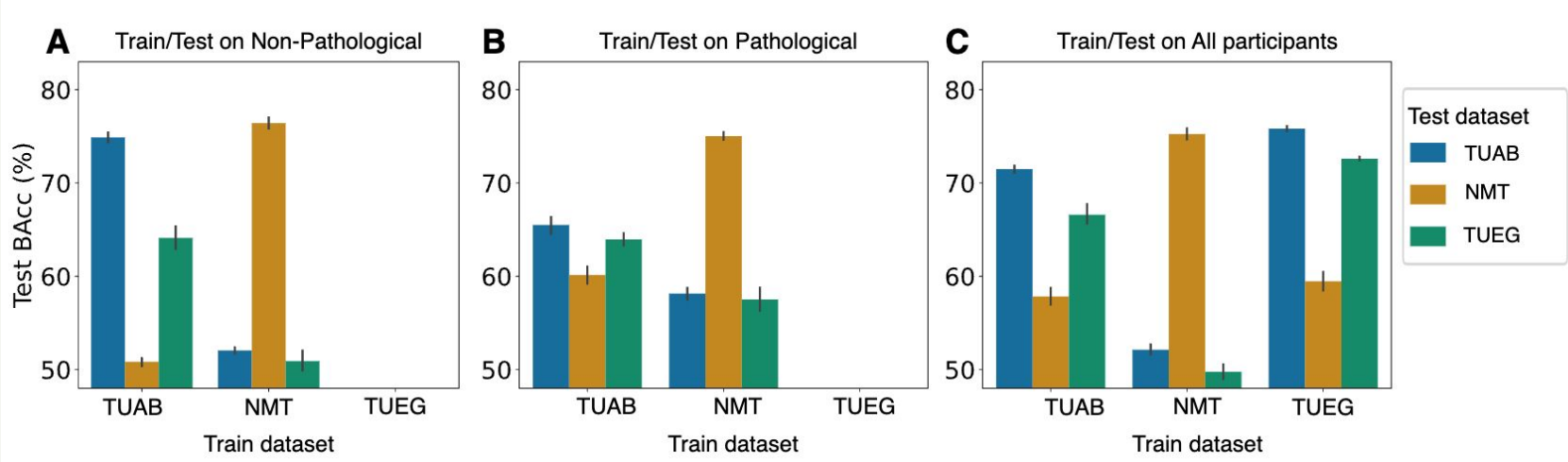


- Three EEG datasets analyzed
- Demographic and Pathological
- Preprocessing: artifact removal
- ShallowNet model
- AdamW optimizer
- BAcc metric (Thölke et al. [2023])
- Target sex or pathology
- Detection and generalization
- Impact of sex imbalances (confounding)
- Visualization: Amplitude Gradient Analysis (AGA)

Sex Detectability (SD) in EEG

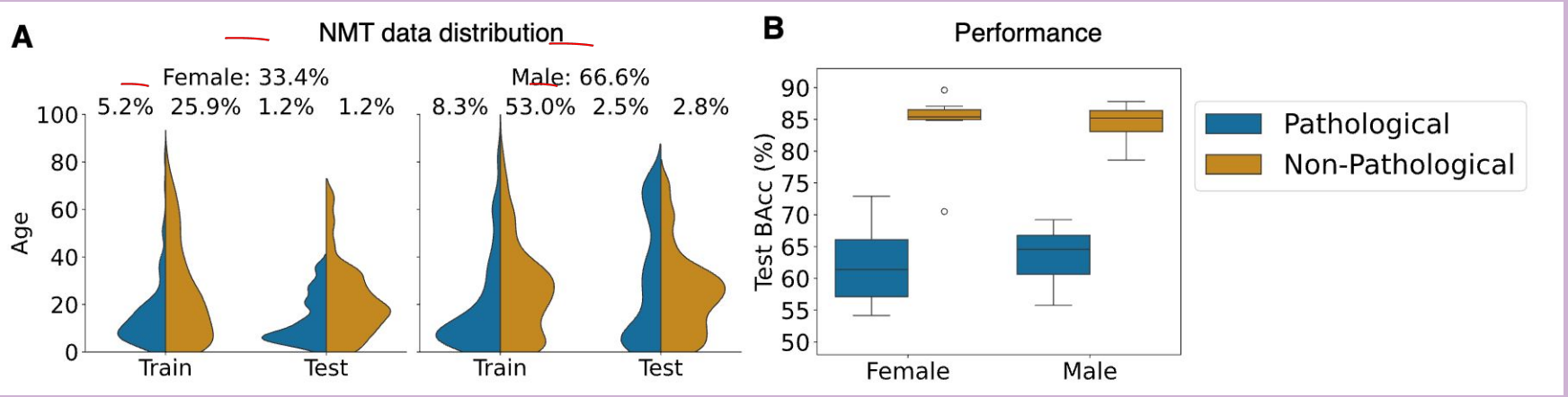
Method	TUAB
Simple CNN on clean data Jochmann et al. [2023]	74.00±02.00
ShallowNet on clean data (Ours)	74.88±01.63
ShallowNet Zero-Shot (Pre-trained-Ours)	**75.83±00.80**

Table 2. Comparison of BAC between previous work on TUAB dataset and ours. Values show mean±SD over 10 randomly initialized models.



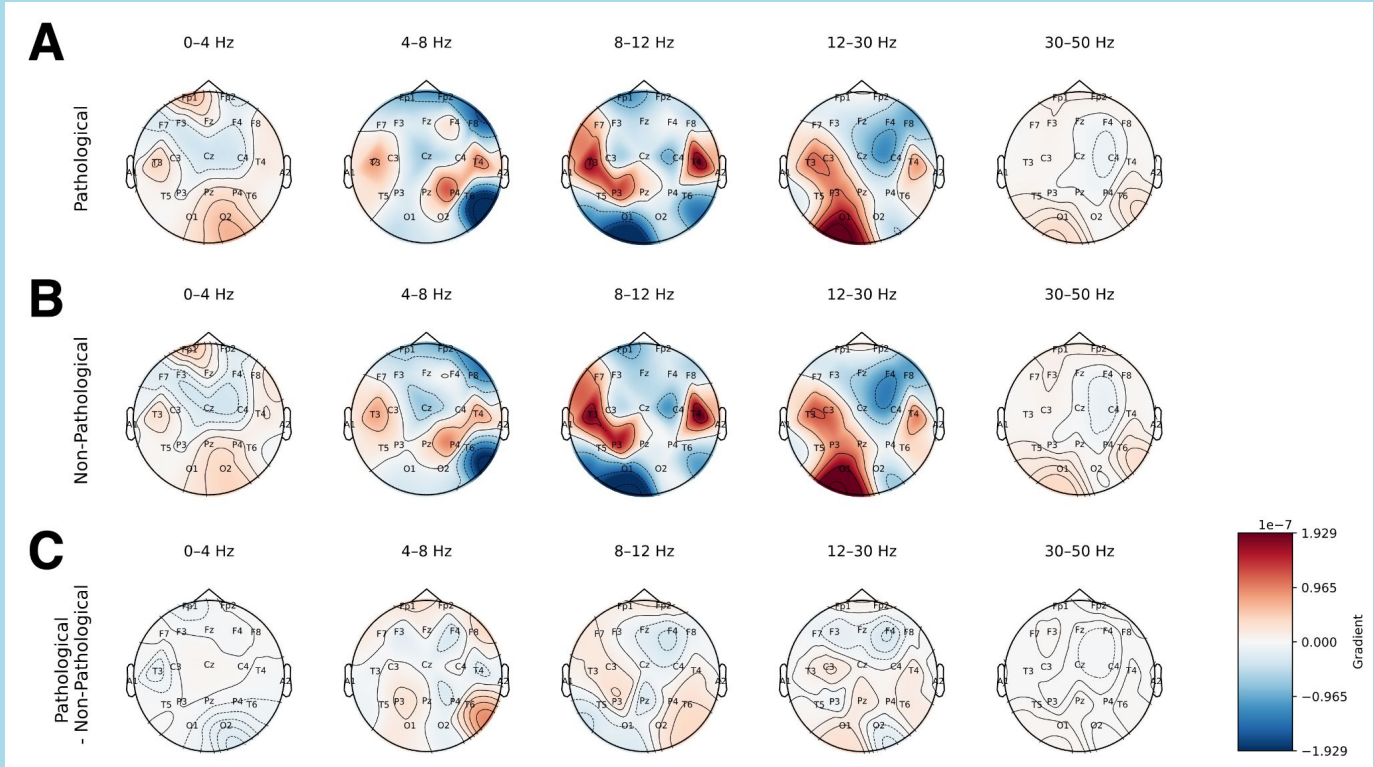
Detectability of sex from EEG signals across three populations: A) Non-Pathological, B) Pathological, C) All Participants. Error bars depict the standard error of BAcc across ten random seeds. Notably, the TUEG dataset lacks pathology labels, rendering results unavailable for A and B. Consequently, results for all participants are visualized in C.

Sex Imbalance's Impact on EEG Pathology Detection



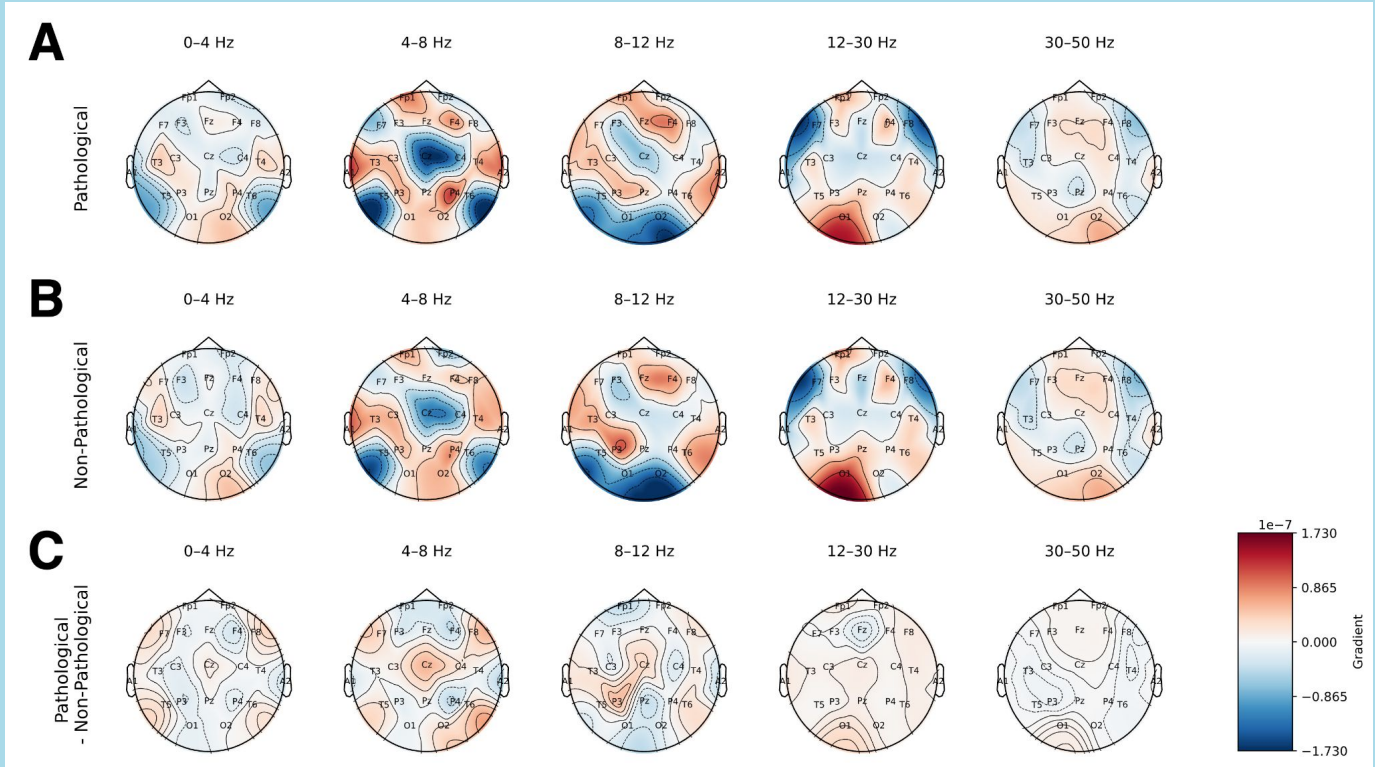
Effect of sex imbalances on pathology detection in the NMT dataset: A) Distribution of male and female samples in the NMT dataset, with the number of male samples being twice as high as that of females. B) Performance (accuracies) of subgroups. The discrepancy in sample numbers does not impact pathology detection.

Feature importance NMT



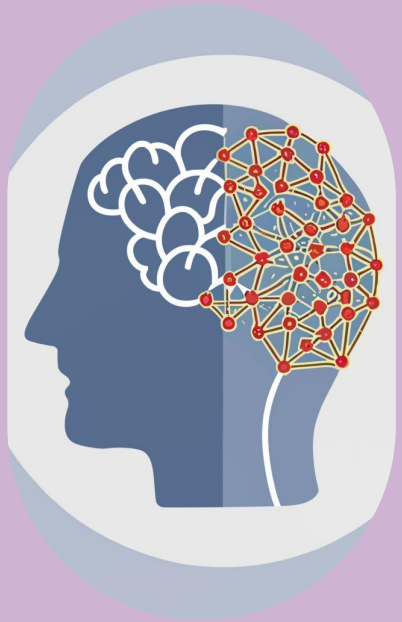
Amplitude Gradient Analysis of different frequency bands of sex classifiers on NMT dataset. A) Pathological, B) Non-Pathological and C) The difference between Pathological and Non-Pathological. The red colour indicates a stronger relation with the female class, while the blue colour indicates a stronger relation with the male class.

Feature importance TUAB



AGA of different frequency bands of sex classifiers on TUAB dataset. A) Pathological, B) Non-Pathological and C) The difference between Pathological and Non-Pathological. The red colour indicates a stronger relation with the female class, while the blue colour indicates a stronger relation with the male class.

Takeaways



- **SD & Distribution Shifts:**
  - Accurate in distribution
  - Diminishes with distribution shifts
- **Sex and Pathology:**
  - Despite consistent patterns
  - Negligible role of sex-specific patterns on pathology detection
  - In some disorders (Khayretdinova et al. [2024])
  - Subtypes (Podcasy and Epperson [2016])
- **Conclusion:**
  - Complex interplay between SD & pathology
  - Pave the way for
    - Personalized
    - Effective interventions
- **Future works:**
  - Robust
  - Explainable

Our Team

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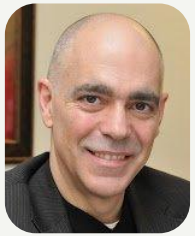

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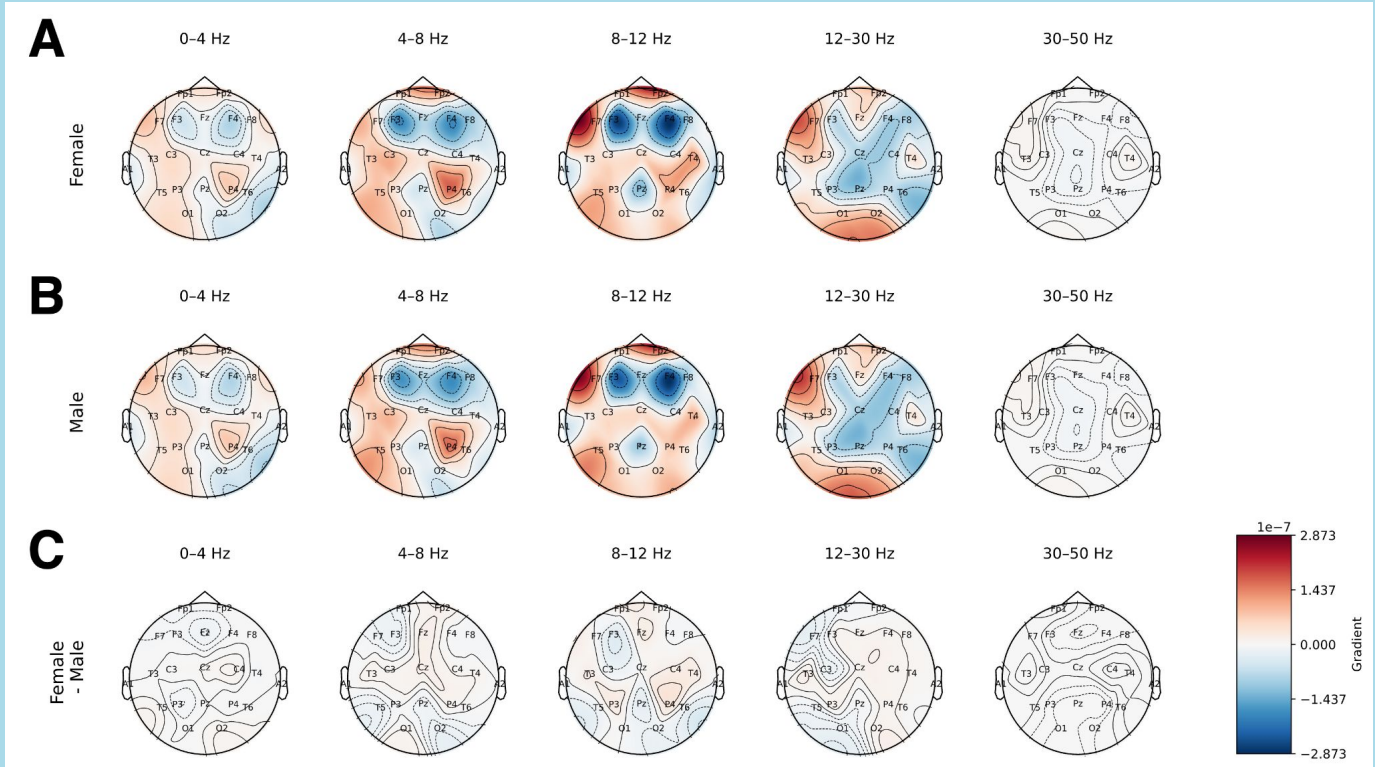
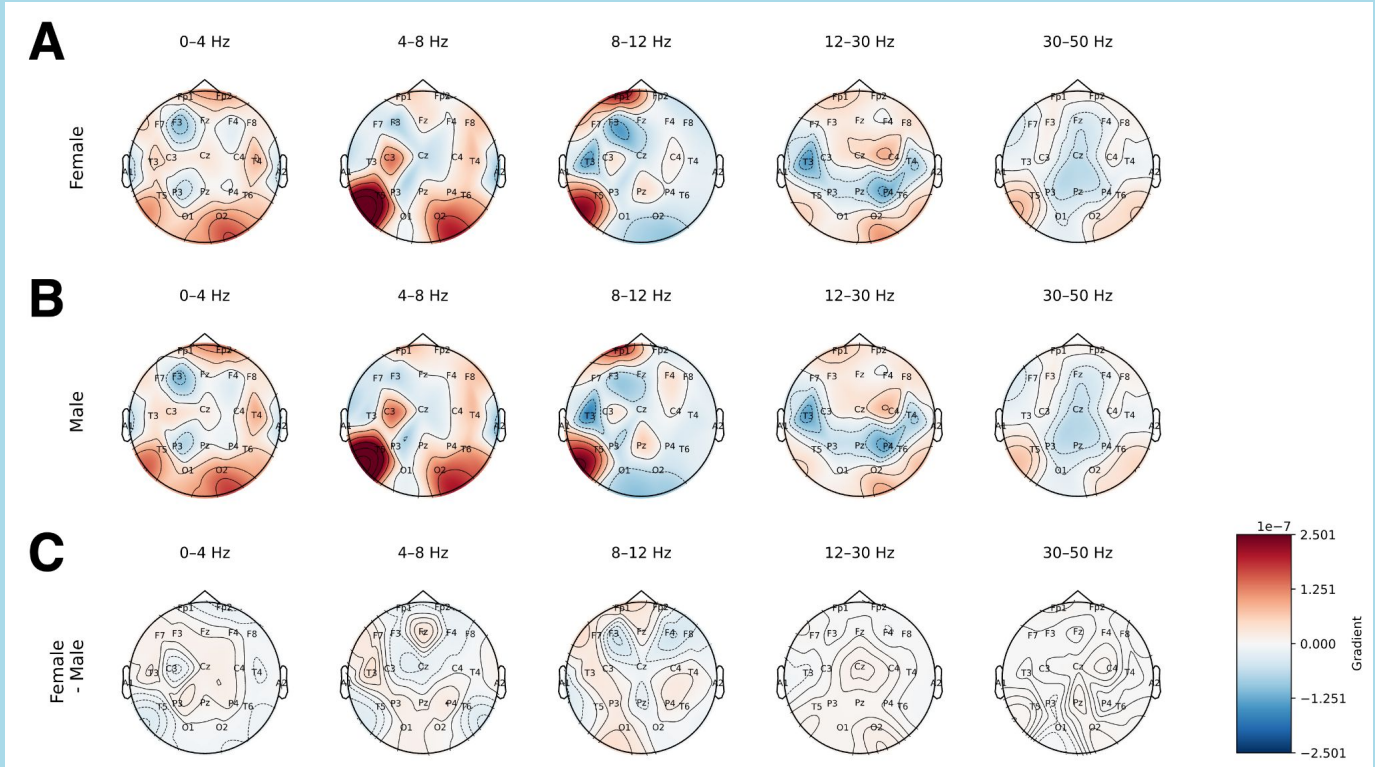
Thank you

Feature importance



Amplitude Gradients Analysis of different frequency bands of Pathology classifiers on NMT dataset. A) Female B) Male C) The difference between Female and Male class. The red colour indicates a stronger relation with the female class, while the blue colour indicates a stronger relation with the male class.

Feature importance



AGA of different frequency bands of Pathology classifiers on TUAB dataset. A) Female B) Male C) The difference between Female and Male class. The red colour indicates a stronger relation with the female class, while the blue colour indicates a stronger relation with the male class.