Decoding Auditory Tones from Brain Signals Recorded using OPM-MEG

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Introduction

- Non-invasive brain-computer interfaces (BCIs) may be a viable tool for communication of individuals with locked-in syndrome (e.g., due to amyotrophic lateral sclerosis) [1].
- Magnetoencephalography (MEG) is a non-invasive neuroimaging technique that records magnetic fields with sub-cm spatial and sub-second temporal resolution.
- By using **optically pumped magnetometers (OPMs) -MEG**, information volume may increase compared to traditional SQUID-MEG systems, leading to higher decoding accuracy of OPM-BCI systems. Yet, no study has evaluated the ability to decode speech using OPM-MEG.

Research Goal

The overarching goal of our research is to utilize an OPM-MEG system to develop a wearable, speech-synthesizing BCI. As a first step, this study investigated the feasibility of detecting auditory tones from OPM-MEG sensors on the left temporal lobe.

Approach

Tonotopy Experiment

- Subjects: 6 healthy participants (3 males/3 females)
- Tones: 500 Hz, 1000 Hz, and 4000 Hz
- Neuroimaging Device: OPM-MEG System [3] with 48 channels

Data Processing

- Bandpass filtered (0.5 – 150 Hz)
- Movement-induced artifacts were removed
- Independent component analysis (ICA) for SNR enhancement

Data Analysis

- Objective: Three-class classification of OPM-MEG signals that correspond to three auditory tones
- Features: Root mean square (RMS), band power, and power spectral density (PSD)
- Decoders: Linear discriminant analysis (LDA) & support vector machines (SVMs) with 4 different kernels
- 6-fold cross validation was used.

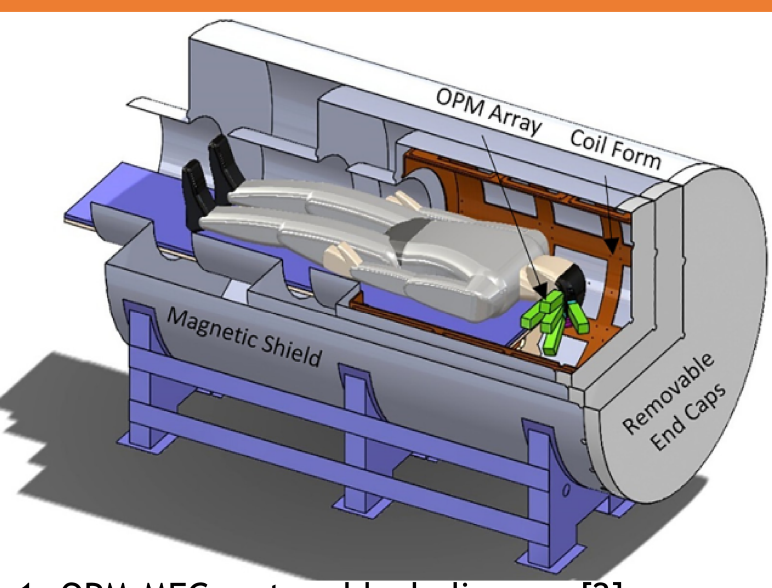

Fig 1. OPM-MEG system block diagram [2]

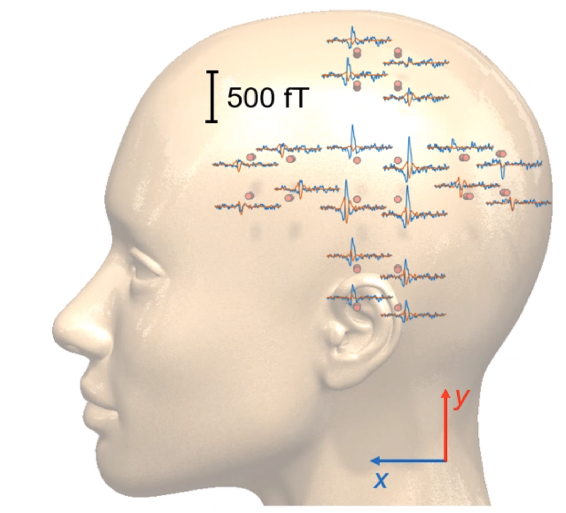

Fig 2. Auditory evoked magnetic fields measured using 20-ch OPM-MEG system [3]

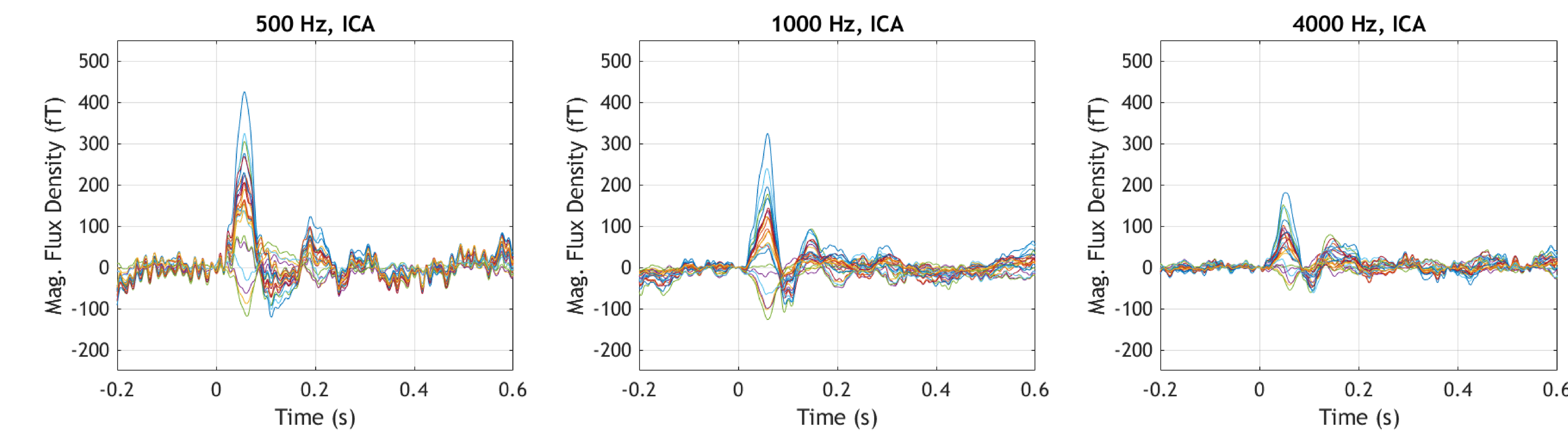

Fig 3. Time-locked, i.e. trial averaged, tonotopy response for a single subject

Preliminary Results

- The average performances for the X and Y tangential components were 62% and 52%, respectively. Both accuracies were significantly above chance level (33%).
- Similar auditory tone decoding performance was robust across all features using LDA (Fig 4) and for the five selected classifiers (Fig 5).

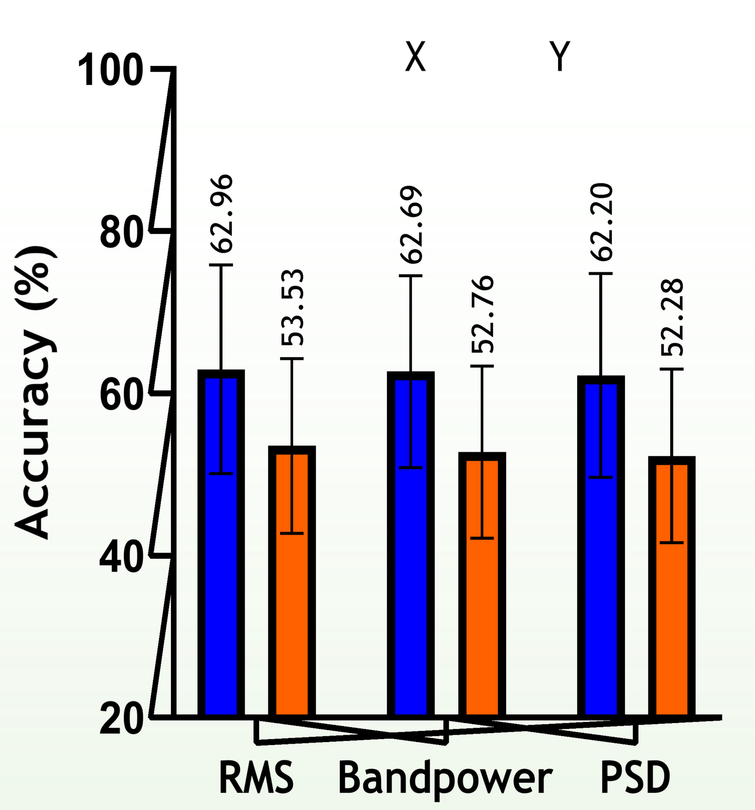

Fig 4. Decoding accuracies using different features (RMS, Band power, and PSD) and LDA

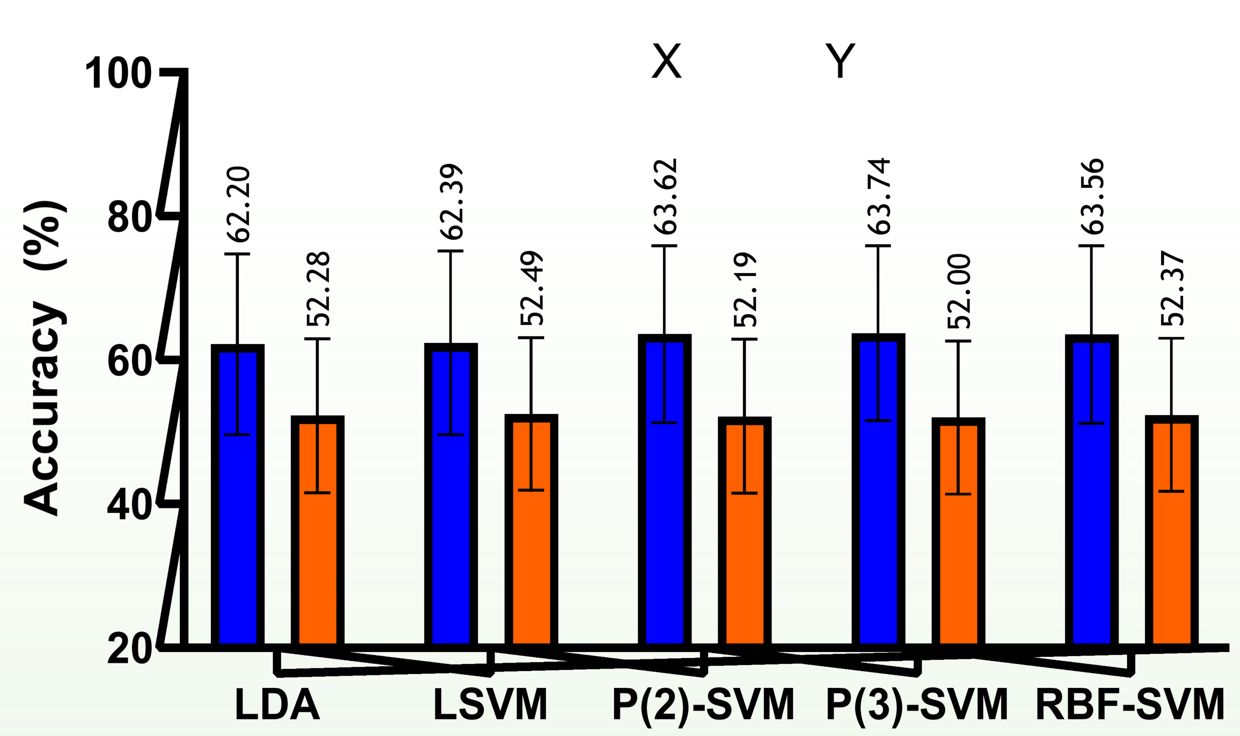

Fig 5. Accuracies obtained using linear and non-linear decoders with PSD feature across all participants

Discussion & Next Steps

- This work provides empirical evidence that our newly developed OPM-MEG system can decode tone information from brain signals.
- Generally, decoding performance using X-components was higher compared to Y-components; the difference was not statistically significant. This is likely less noise evident in the X-component signals.
- Similar decoding performance was evident across the three features and decoders (both linear and non-linear), suggesting that the decoding is robust.
- Next steps include applying additional feature engineering techniques and leveraging temporal information to train sequential neural networks (e.g., LSTM) to improve performance.

Future Works

- Collect imagined and overt speech data for decoding analysis
- Closed-vocabulary decoding performance using OPM-MEG signals and compare to that using traditional SQUID-MEG [1]
- Open-vocabulary decoding

Acknowledgments

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References

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