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# Single-trial classification of evoked responses to auditory tones using OPM- and SQUID-MEG

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## Introduction

Optically pumped magnetometers (OPMs) are a near-room-temperature alternative to superconducting quantum interference devices (SQUIDs) for magnetoencephalography (MEG). In contrast to SQUIDs, OPMs can be placed in a close proximity to subject's scalp potentially increasing the signal-to-noise ratio and spatial resolution of MEG [1]. However, experimental demonstrations of these benefits are still scarce.

To compare our 24-channel OPM-MEG system [2] to a commercial whole-head SQUID system (MEGIN Oy) in a data-driven way, we quantified their performance in classifying single-trial evoked responses to auditory tones in six participants.

We performed

- Pairwise temporal classification of the responses
  - Linear discriminant analysis (LDA)
- Multiclass classification
  - EEGNet convolutional neural network [3]
  - xDAWN decoding + Riemannian geometry + Logistic regression [4,5]

## Methods

**Stimuli**

- Binaural sinusoidal tone pulses (0.5, 1 and 4 kHz)
- Pulse duration: 50 ms, ISI: 650 ms, jitter: 100 ms

**Preprocessing**

- SQUID: MaxFilter
- LDA: bandpass filter at 1—90 Hz
- EEGNet: 1—43 Hz; downsample to 128 Hz
- Independent component analysis (ICA) data cleaning
- Classification: Equalize epoch counts for OPM and SQUID

**LDA**

- Principal component analysis (PCA) to 99% variance
- 10-fold cross validation (CV), 9:1 training-to-test ratio

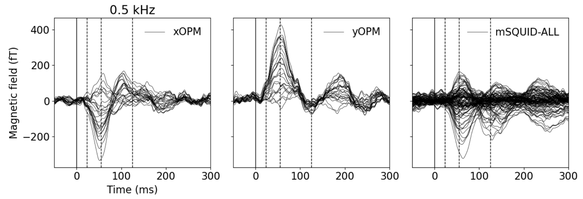
**EEGNet**

- $F_1 = 8$, $D = 2$, $F_2 = 16$; kernel length: 64 samples; dropout rate: 0.5
- 4-fold CV: training:validation:test split ratio 2:1:1

**xDAWN + Riemannian Geometry + Logistic regression**

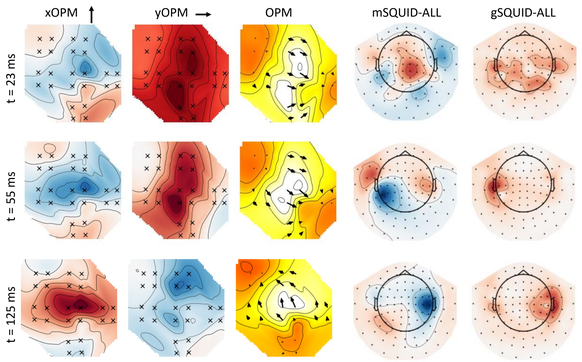
- 4-fold CV: training:test split ratio 3:1

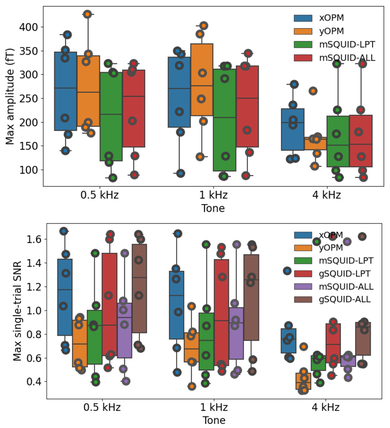
## Evoked responses




- Example evoked responses from a single subject.
- mSQUID/gSQUID: SQUID magnetometers/gradiometers.

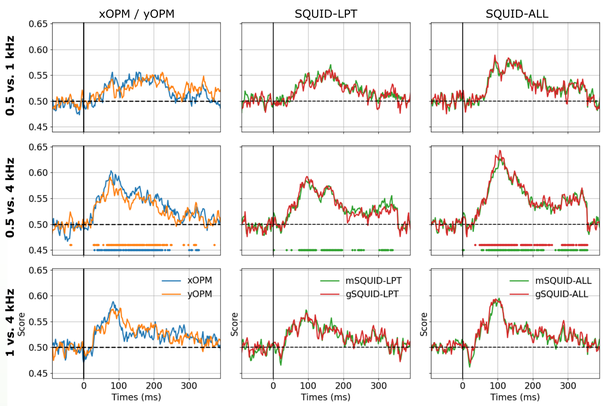
- The field patterns of the responses at indicated time instants.
- Removed ICA components (average over participants)
  - OPM: 5
  - SQUID: 2

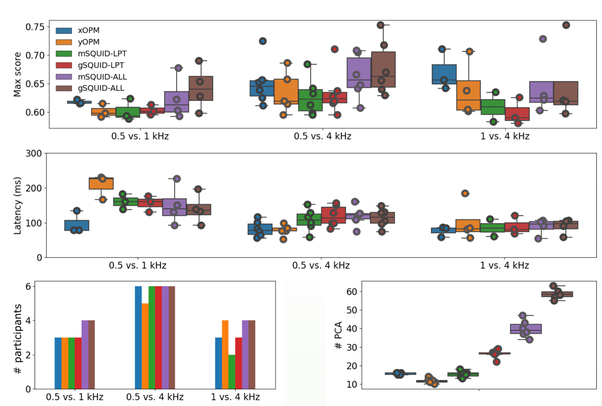



- The maximum evoked-response amplitude and single-trial SNR across the participants, arrays and tones.
- SQUID-LPT: left parietotemporal SQUIDs (26/52 chs)
- SQUID-ALL: All SQUIDs (102/204)

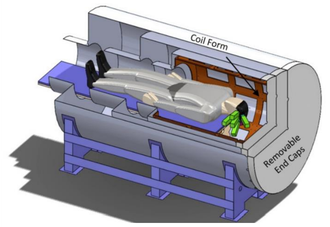
## LDA classification

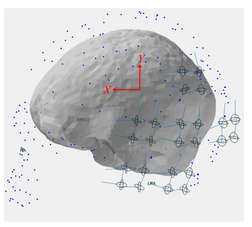



- The average classification accuracy of LDA across the participants as a function of time.
- The points underneath the plots show time instances when the accuracy is significantly higher than the chance level ($p < 0.05$).
- Summary of the classifier performance across the participants. The maximum classification accuracy and its latency. Dot = a participant.
- The number of participants that showed a time instant with significant classification accuracy.
- The number of PCA components needed to explain 99% of the data variance.

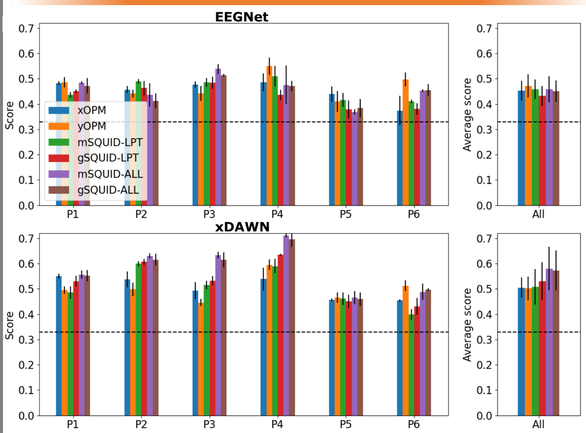
## OPM-MEG system



- 24-channel OPM-MEG system inside a person-sized magnetic shield [2].
- The locations and orientations of xOPM and yOPM with respect to a subject's brain surface.
- xOPM and yOPM are measured sequentially.

## EEGNet and xDAWN




- The classification accuracies of EEGNet and xDAWN spatial filtering across the participants

## Conclusions

- OPMs provided higher classification accuracies than SQUIDs having a similar coverage of the left hemisphere of the participant.
- SQUID sensors covering the whole helmet had classification scores larger than those of OPMs demonstrating the benefits of a whole-head measurement.
- Simultaneous measurement of xOPM and yOPM may yield even higher accuracies.

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[1] J. Iivanainen, *et al.*, NeuroImage, 147, 542-553 (2017)
[2] A. Borna, *et al.*, Phys Med Biol, 62(23), 8909 (2017)
[3] V. J., Lawhern, *et al.*, J Neural Eng, 15(5), 056013 (2018)
[4] B. Rivet, *et al.*, IEEE Trans Biomed Eng, 56(8), 2035-2043 (2009)
[5] A, Barachant, *et al.*, IEEE Trans Biomed Eng, 59(4), 920-928 (2011)

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