DEPARTMENT OF PSYCHOLOGY
NEUROPSYCHOLOGY LAB

CARL VON OSSIETZKY universität OLDENBURG

AN ARTIFACT CORRECTION METHOD FOR EEG DATA USING RIEMANNIAN GEOMETRY

Sarah Blum, Bojana Mirkovic, Stefan Debener

Neuropsychology Lab, Department of Psychology, European Medical School, University of Oldenburg, Germany

INTRODUCTION

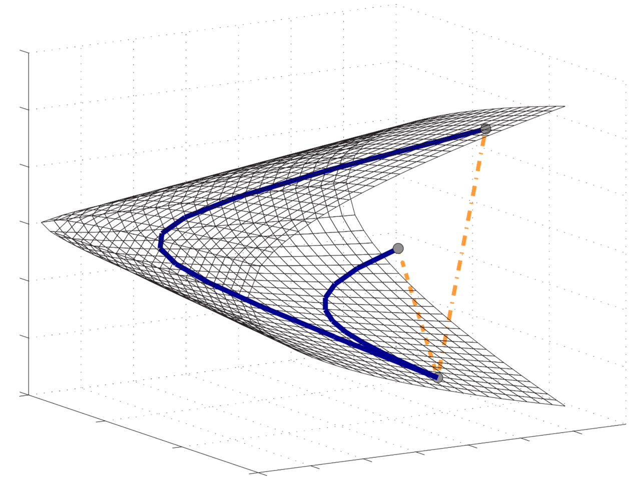
We adapted Artifact Subspace Reconstruction (ASR) [1], an artifact attenuation method for EEG data by replacing core computations using Riemannian geometry. ASR as well as our Riemannian ASR version need clean calibration data to compute a model of artifact-free EEG data. After this calibration it works without supervision.

Our method, Riemannian ASR **(rASR)** computes a geometry-aware principal component analysis on covariance matrices of the channel data to detect artifacts based on their statistical properties in the component subspace.

We previously showed that rASR attenuates typical EEG artifacts successfully in cap EEG data. Here we extend our analyses to sparsely recorded EEG using the cEEGrid, a behind-the-ear sensor grid [ceegrid.com].

We find that rASR corrects typical EEG artifacts while preserving the signal of interest in data recorded with behind the ear EEG sensors.

METHODS



Riemannian (blue lines) and Euclidean distance (orange line) measures. Adapted from [2].

We used EEG data from 16 subjects, sitting still in the lab, data were recorded with the cEEGrid and a cap simultaneously.

Participants were asked to clench their jaw or speak during the artifact production task. During the alpha task, they were sitting still with eyes closed.

We evaluated the correction of EMG artifacts and the preservation of the power and spatial distribution of the alpha oscillation (8-13 Hz) by computing a spectrum of the EEG data for the respective conditions. After filtering, data were either artifact-corrected using rASR or not further processed.

RESULTS

asr_calibrate

filter incoming data

calculate sample covariance matrix

calculate mixing matrix

calculate threshold matrix

asr_process

filter incoming data

calculate covariance matrix

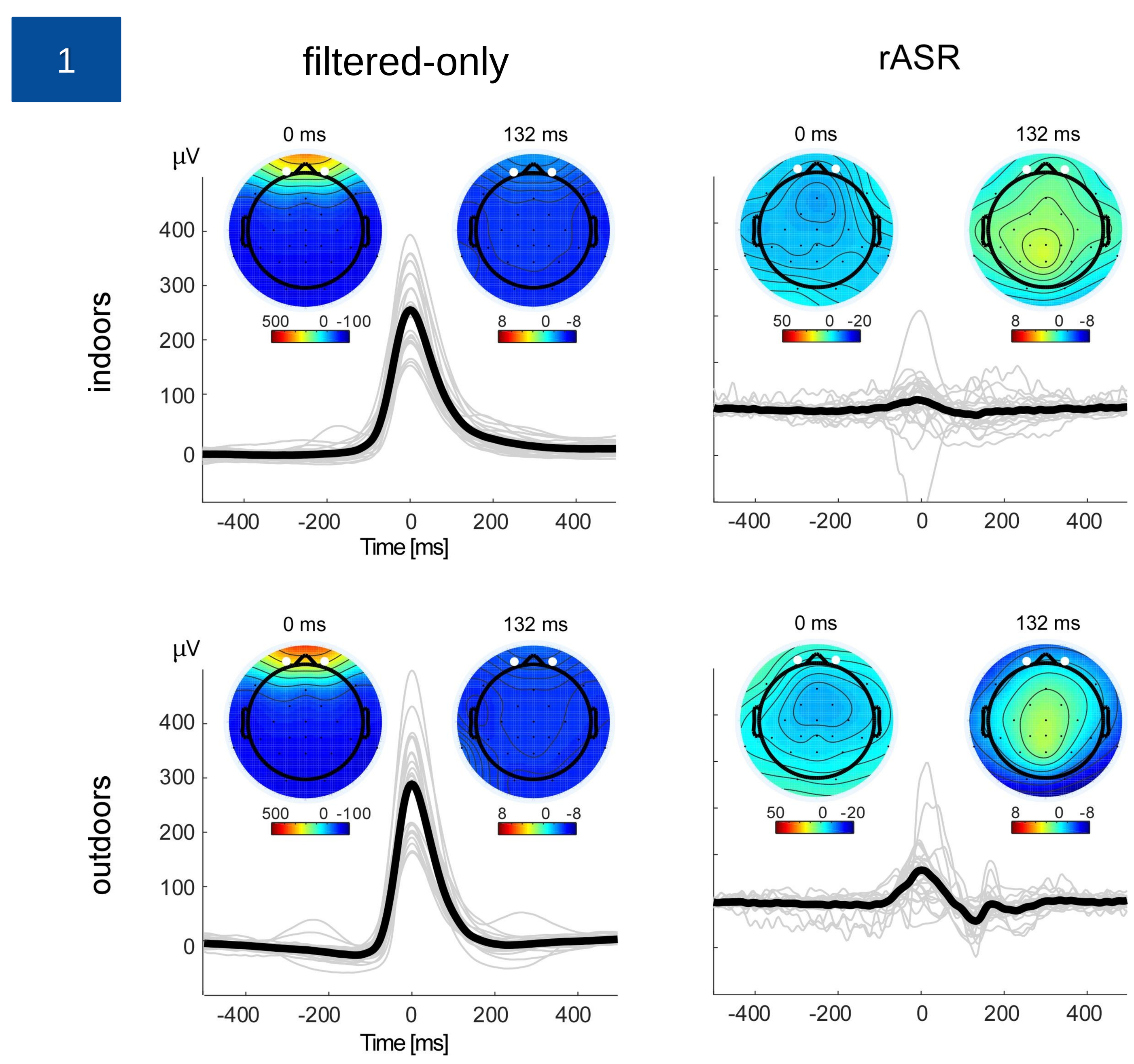
eigendecomposition of covariance matrix

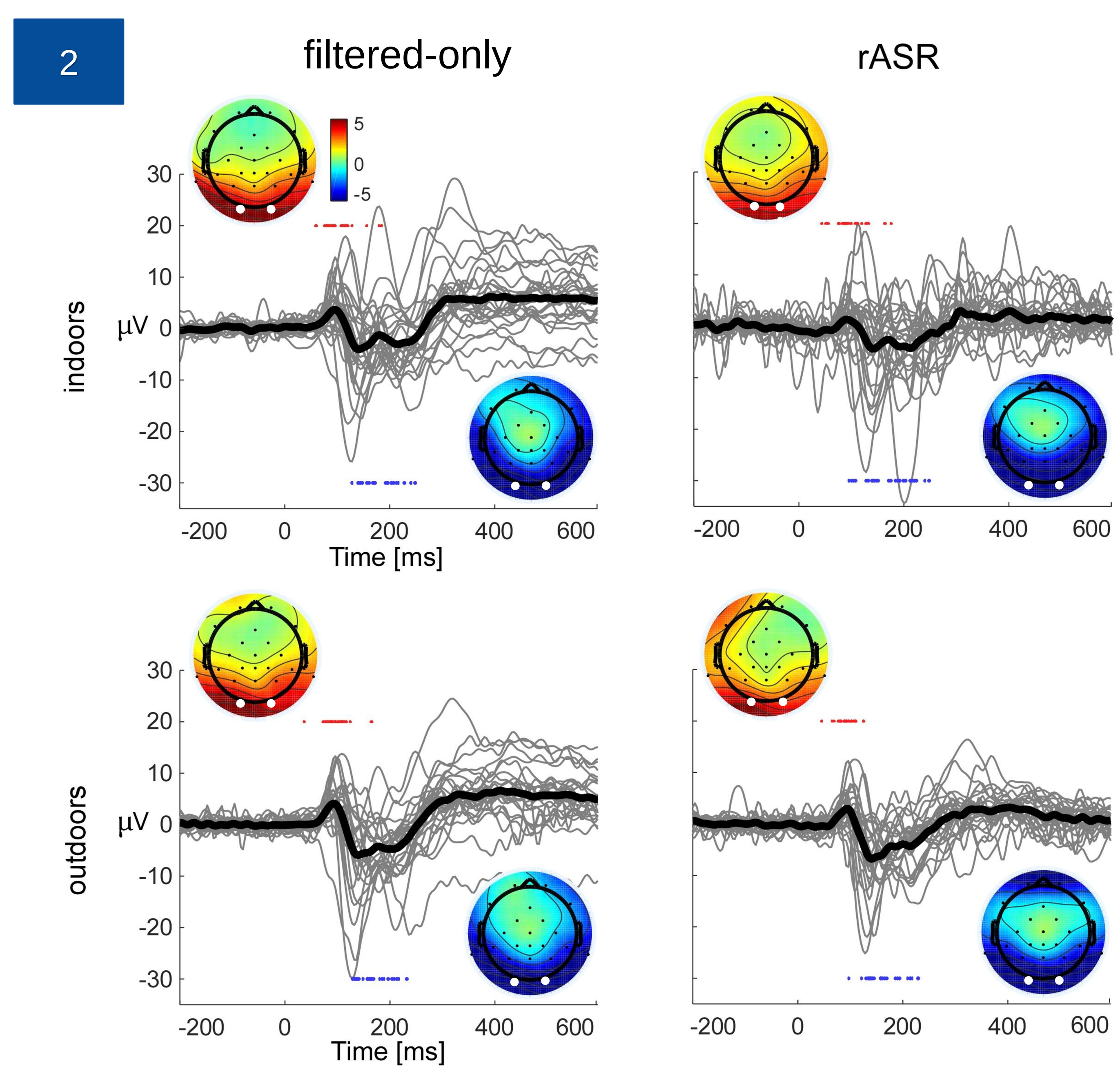
choose clean components

reconstruct data segment

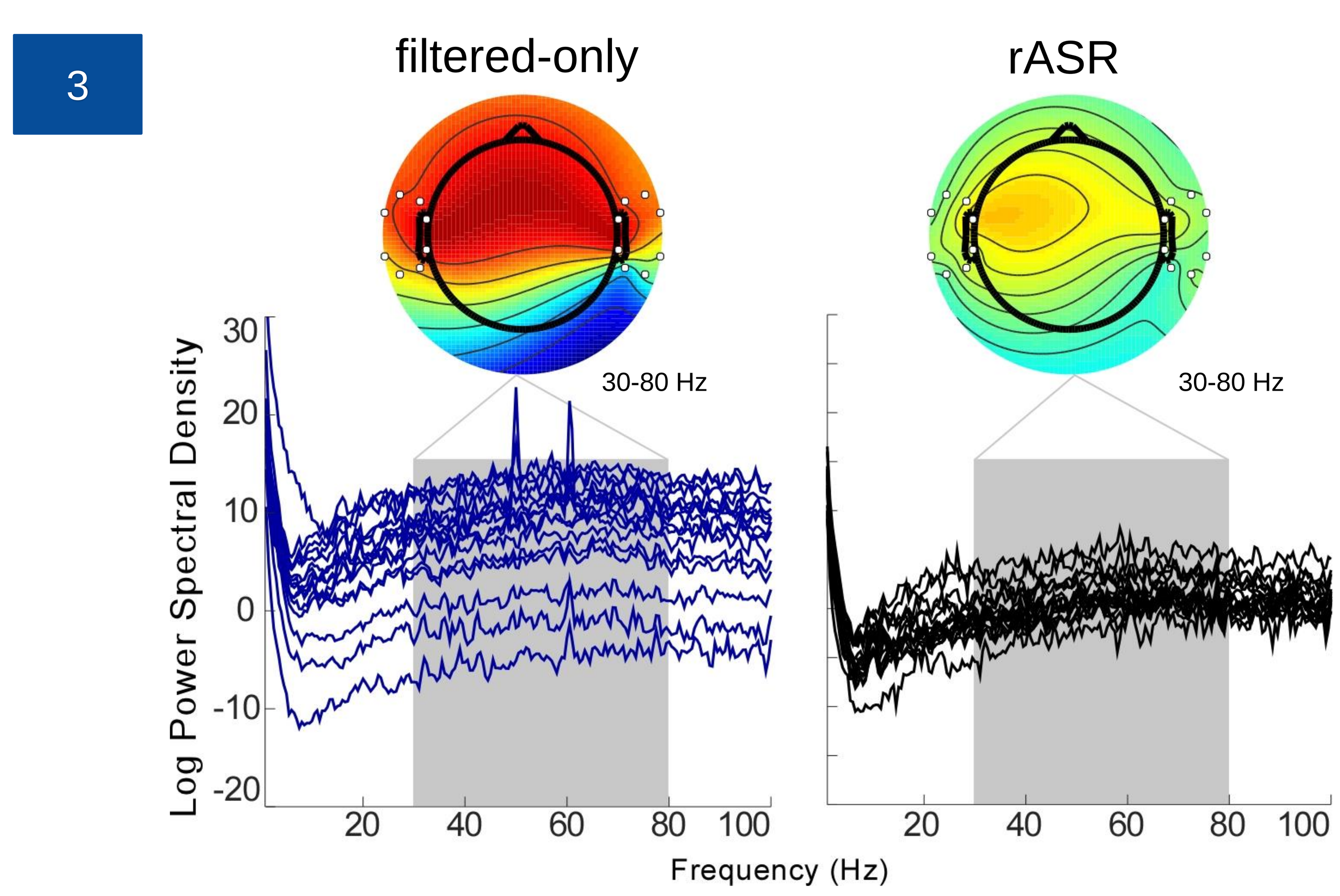
The ASR core algorithm consists of two main methods: **calibration** and **processing**. Dashed lines indicate parts adapted with Riemannian geometry in rASR.

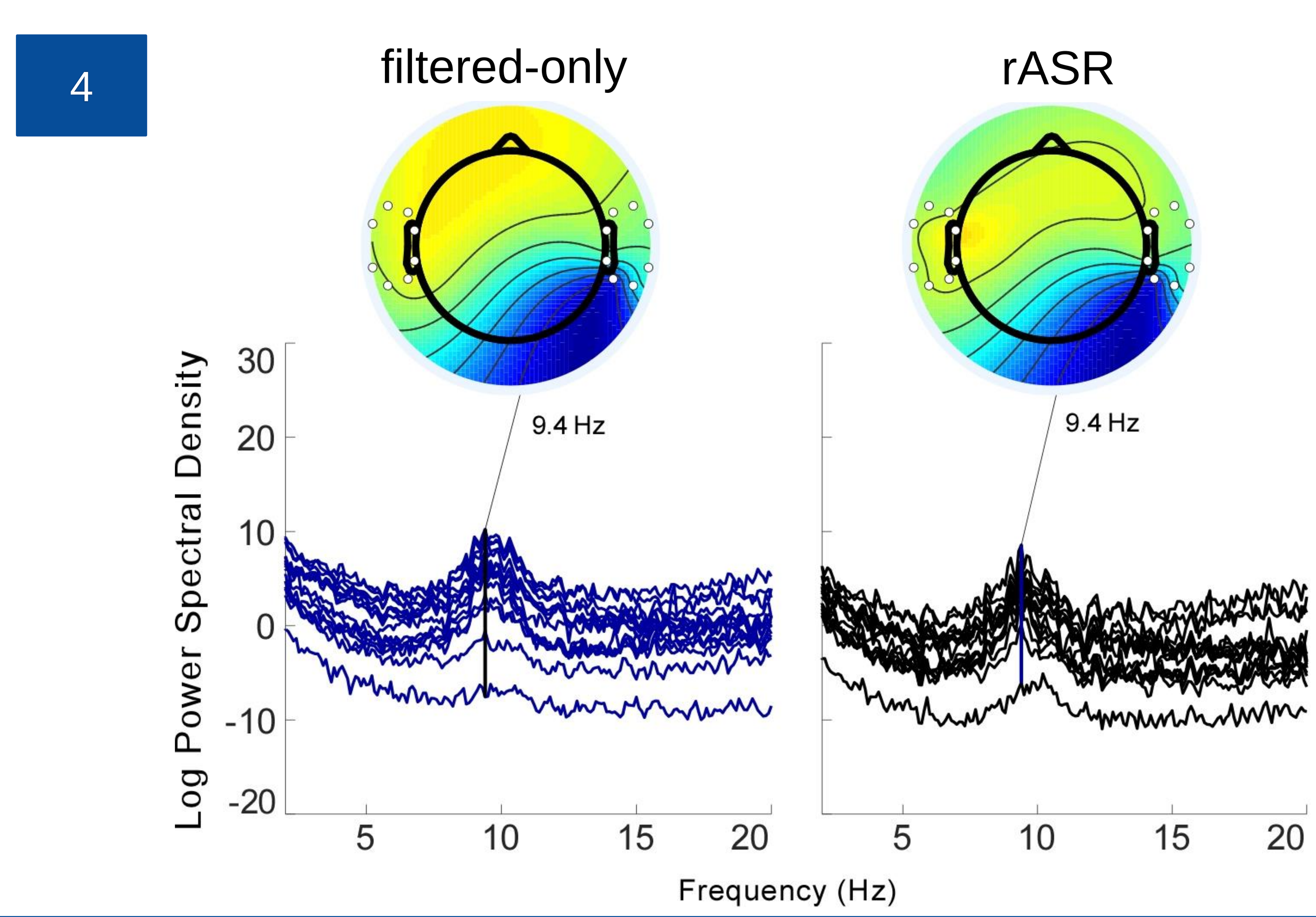
In a previous investigation, we found that rASR successfully corrects eye blinks **(1)**, while retaining the signal of interest in the EEG, here a visual evoked potential **(2)**. These data were recorded using a mobile EEG cap [3]. Particpants were either standing indoors or outdoors and were asked to memorize words displayed on a smartphone screen. Every presented word elicited a VEP. The blinks were detected in the ongoing EEG signal using the Blinker toolbox [4]. White channels on the topoplot indicate the channels used for the grand average signal (bold black line), grey thin lines show the subject average responses.





Results from our newest investigation indicate that rASR also performs well using the cEEGrid instead of the EEG cap. rASR successfully corrects the muscle artifact in the spectrum **(3)**, which is visible in the uncorrected channels on all frequencies, while the spectrum of the rASR-corrected data shows an overall reduced power. The right figure **(4)** shows the preserved alpha frequency and spatial distribution: we see a clear peak in the spectrum on all channels in the alpha range (8-13 Hz). The power is not reduced in the rASR-corrected data and the spatial distribution remains unchanged by rASR.





SUMMARY

Riemannian ASR successfully detects and corrects muscle artifacts, as well as eye-blinks in the EEG data without user supervision or input.

At the same time, Riemannian ASR preserves the signal of interest in its amplitude, frequency and spatial properties as indicated by the evaluation of the spectrum and time-domain of the EEG data

We evaluated rASR for a visual evoked potential elicited by a stimulus on the smartphone and the alpha frequency recorded in a resting condition with eyes closed

CONCLUSION

Riemannian ASR is an unsupervised, online artifact attenuation method suitable for the usage in mobile recording conditions. It attenuates artifacts in traditional EEG recordings recorded with a cap and also in recordings using fewer electrodes behind the ear.

Further evaluations are necessary to investigate the parameters of rASR and their application in mobile, low-density EEG recording using the smartphone

With the addition of Riemannian methods to ASR, we present a fast and reliable artifact correction method. Source code here: **github.com/s4rify**

[1] **Mullen et al. (2015).** Real-Time Neuroimaging and Cognitive Monitoring Using Wearable Dry EEG. IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING, VOL. 62, NO. 11
[2] **F. Yger, F. Lotte and M. Sugiyama (2015).** Averaging covariance matrices for EEG signal classification based on the CSP: An empirical study. 23rd European Signal Processing Conference (EUSIPCO), pp.2721 2725, 2015
[3] **Blum et al. (2019).** A Riemannian Modification of Artifact Subspace Reconstruction for EEG Artifact Handling. Frontiers in Human Neuroscience, Vol. 13, p. 141-156
[4] **Kleifges K, Bigdely-Shamlo N, Kerick S E and Robbins K A** (2017). BLINKER: Automated Extraction of Ocular Indices from EEG Enabling Large-Scale Analysis Frontiers in Neuroscience Vol. 11