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Evaluation of Riemannian Artifact Subspace Reconstruction for the Correction of EEG Artifacts

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Introduction

- We investigated an artefact attenuation method for mobile EEG data based on Artifact Subspace Reconstruction (ASR) [1] using Riemannian geometry
- ASR computes a principal component analysis on covariance matrices of the channel data to detect artifacts based on their statistical properties in the component subspace
- Once an artifactual segment has been detected, it is reconstructed with estimated clean EEG data
- We find that our adaptation Riemann ASR **(rASR)** detects typical EEG artifacts while preserving the signal of interest. The computing time has been reduced by a third compared to original ASR (both Matlab toolboxes)

Methods

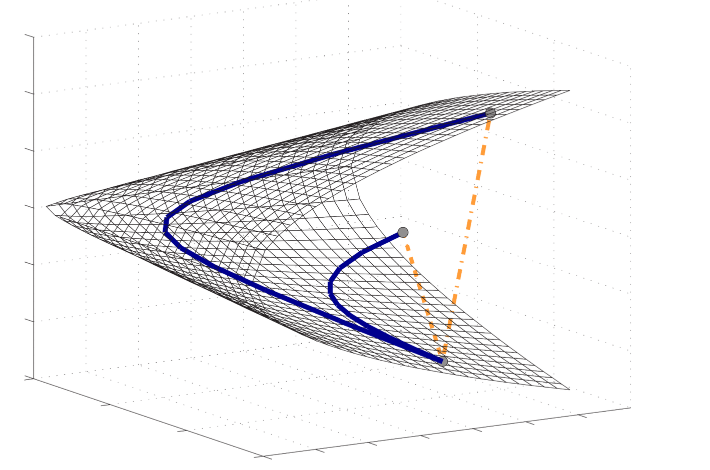

Figure 1: Riemannian (blue lines) and Euclidean distance (orange line) measures. Adapted from [2].

- EEG data from 11 subjects, sitting still and walking outdoors, data recorded with mobile EEG hardware and a smartphone
- Artifact attenuation was done using traditional ICA, standard ASR and our Riemann ASR
- Riemannian geometry was added to ASR in the estimation of the sample covariance matrix and the averaging of covariance matrices [after 2, 3]
- Computations in Matlab were done using the Manopt toolbox [4]

Results

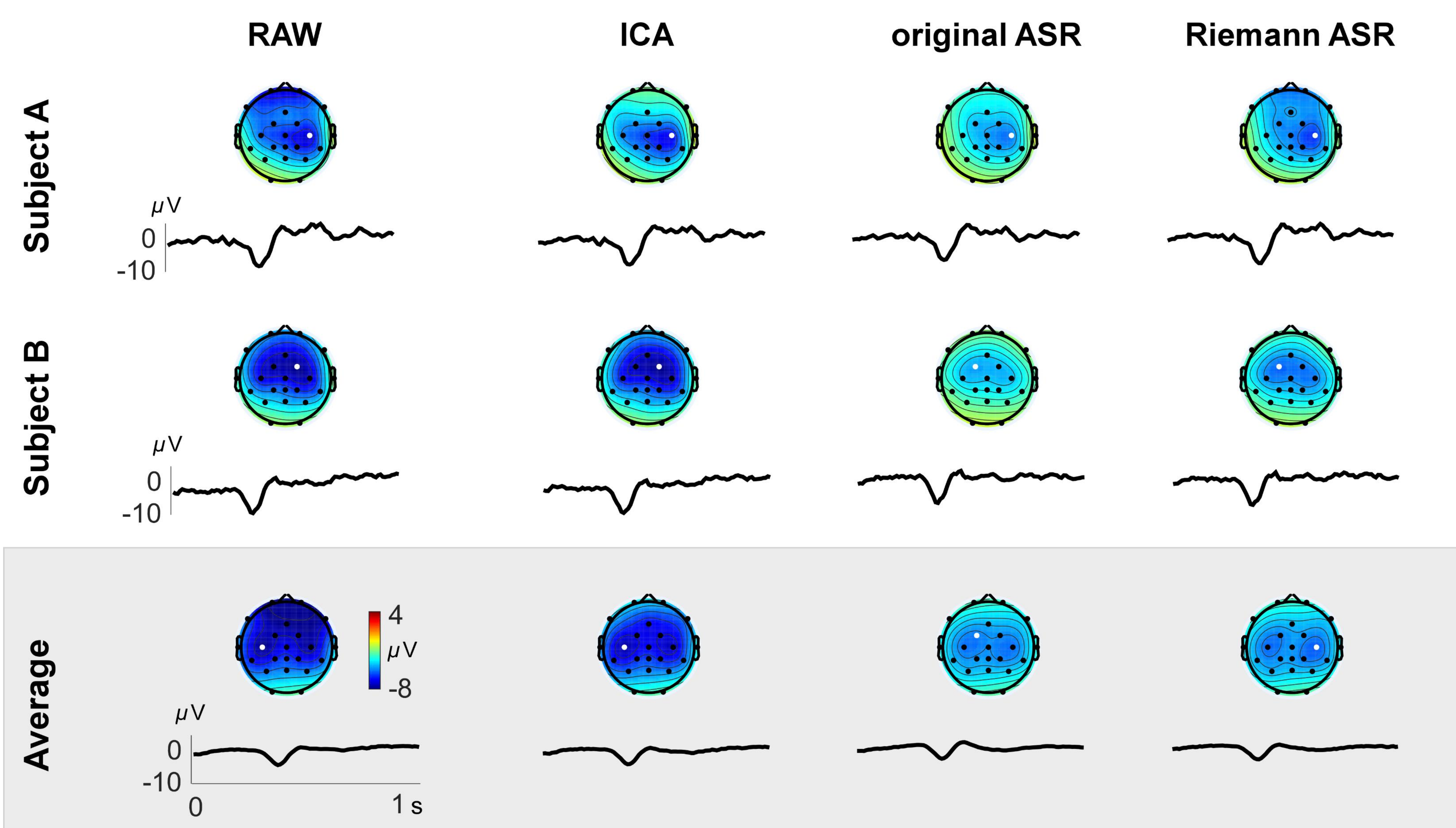

Figure 2: N100 signals for two single subjects and the grand average over all subjects Computation for n > 200 trials per subject. We find that rASR contains the N100 and improves its signal to noise ratio (SNR).

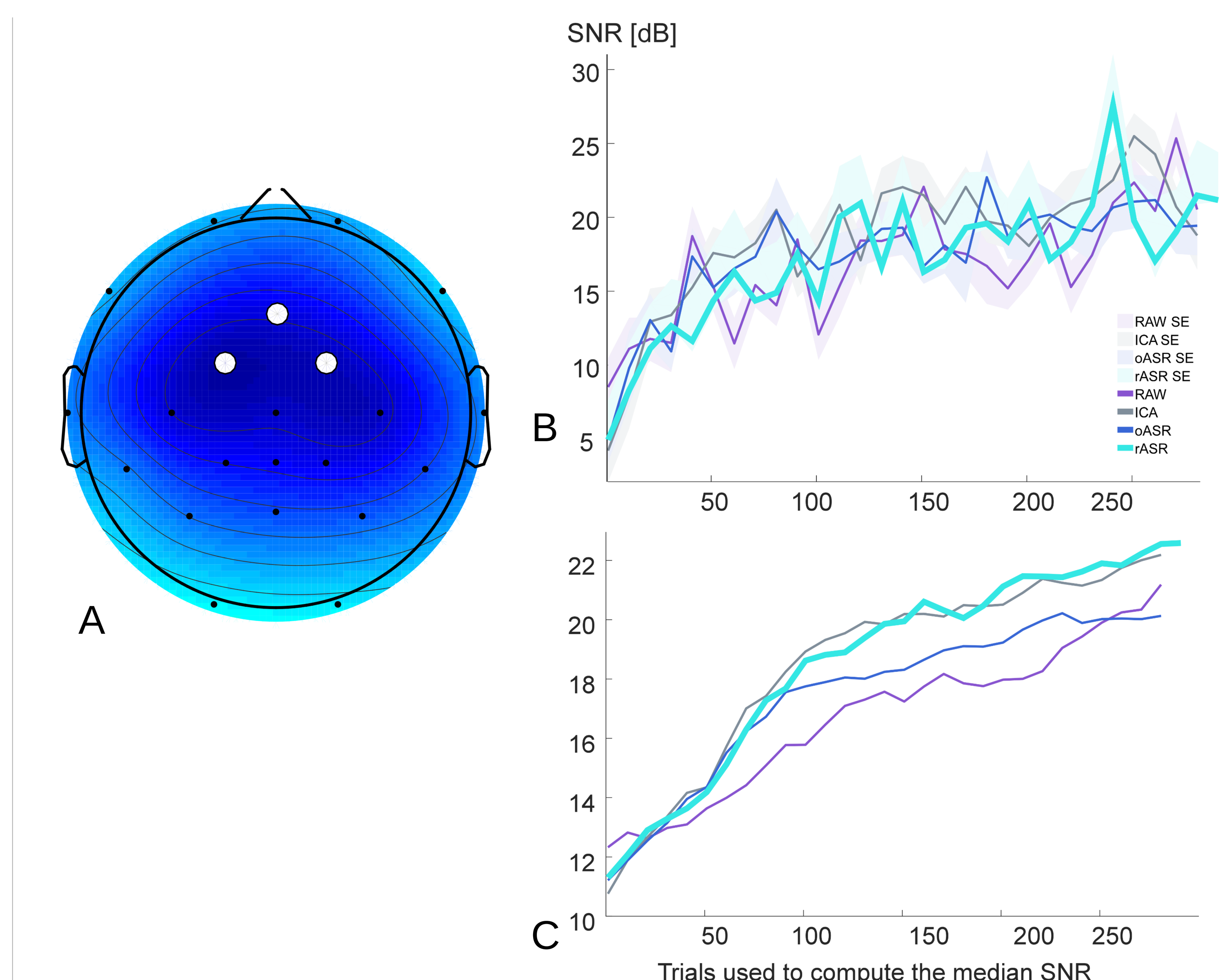

Figure 3: SNR of the N100 for a representative subject. **A** Topoplot indicating the channels which were used to compute the ERP. **B** Improvement of N100 SNR with increasing amount of trials. **C** Moving mean of the SNR value with increasing amount of trials.

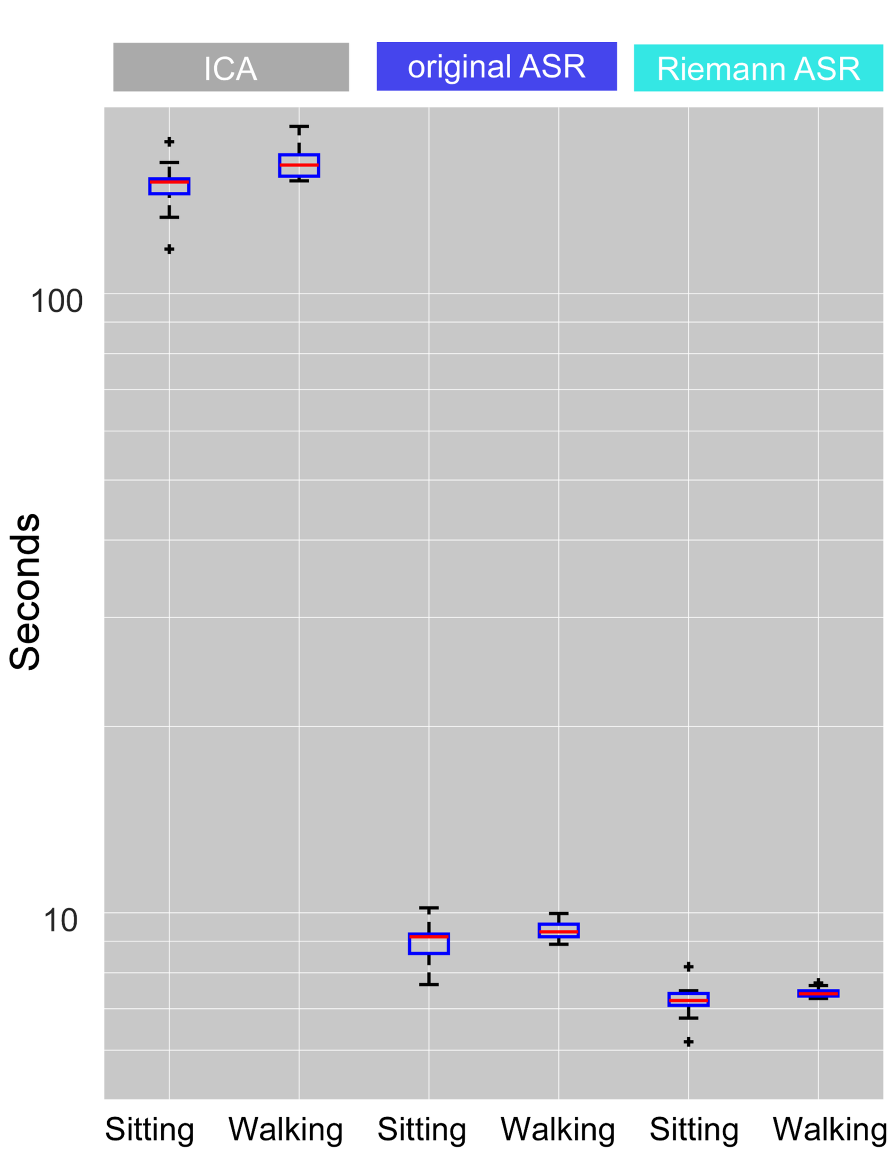

Figure 4: Computing time of data cleaning for all subjects and both conditions.

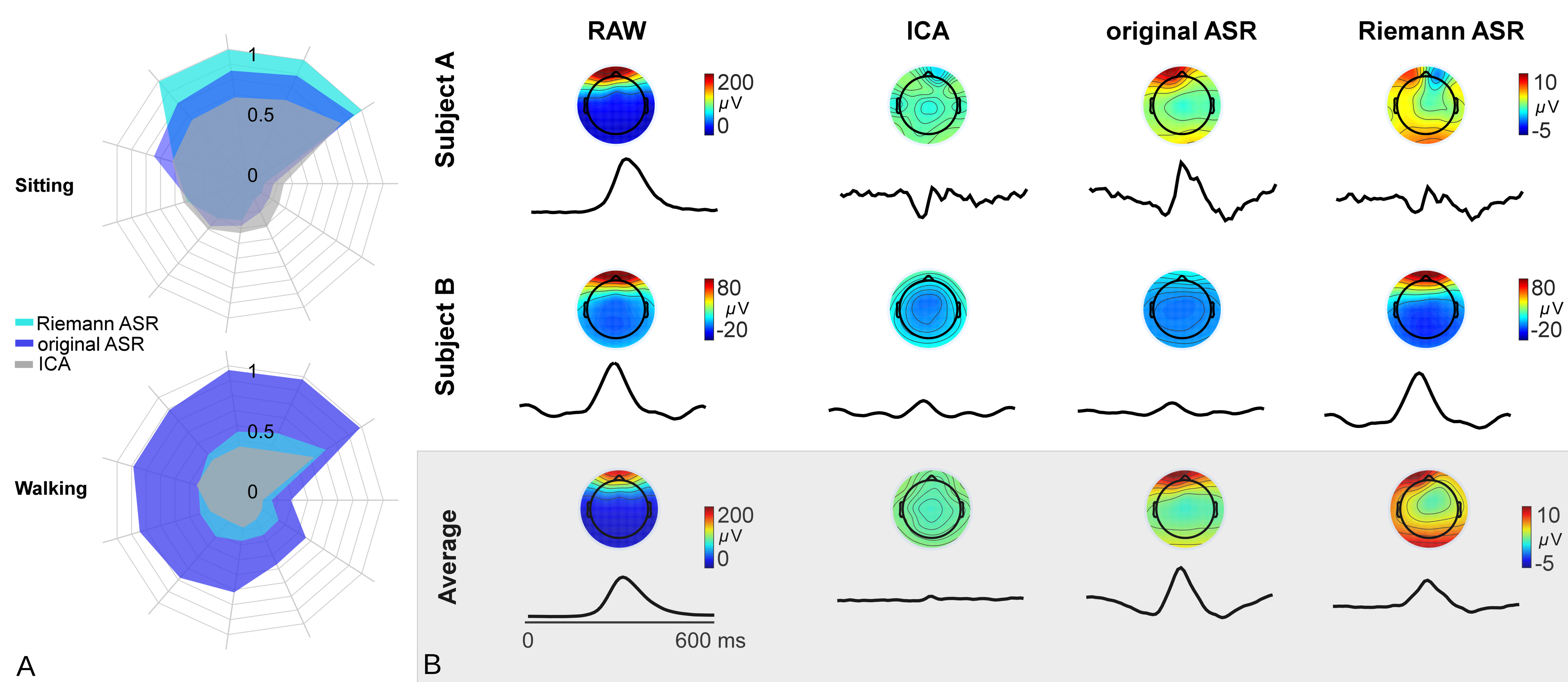

Figure 5: **A** Correlation of corrected blink maps to raw blink maps for EEG data while sitting and walking. Each spoke represents one subject. Small correlation values indicate a good artifact attenuation. **B** Blink artifacts for two single subjects and the grand average over all subjects. Blinks have been detected in the raw EEG signal, the index was then used to epoch the data on the artifact. rASR detects and corrects blink artifacts. Without explicit calibration data, the blink is not detected in all subjects (middle row).

Conclusion

- Riemann ASR detects and corrects eye blinks. Its sensitivity is comparable to original ASR
- Riemann ASR preserves signal of interest and improves the SNR. Its specificity is comparable to original ASR
- The computing time in Matlab has been reduced by a third. This makes rASR interesting for mobile applications
- The code is available in a Matlab toolbox and will be implemented in a Java library for smartphones soon

References

[1] T. R. Mullen et al., "Real-time neuroimaging and cognitive monitoring using wearable dry EEG", in IEEE Transactions on Biomedical Engineering, vol. 62, no. 11, pp. 2553-2567, Nov. 2015

[2] F. Yger, F. Lotte and M. Sugiyama, "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] F. Yger, M. Berar, F. Lotte, "Riemannian approaches in Brain-Computer Interfaces: a review.", in IEEE transactions on Neural Systems and Rehabilitation Engineering, Institute of Electrical and Electronics Engineers, 2017

[4] N. Boumal, B. Mishra, P.-A. Absil, R. Sepulchre, "Manopt, a Matlab Toolbox for Optimization on Manifolds", in Journal of Machine Learning Research, vol.15, pp.1455-1459, April 2014

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