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EEG-Based Decoding of the Spatial Focus of Auditory Attention Using Riemannian Geometry-Based Classification

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Auditory Attention Decoding in Smart Neuro-Steered Hearing Devices

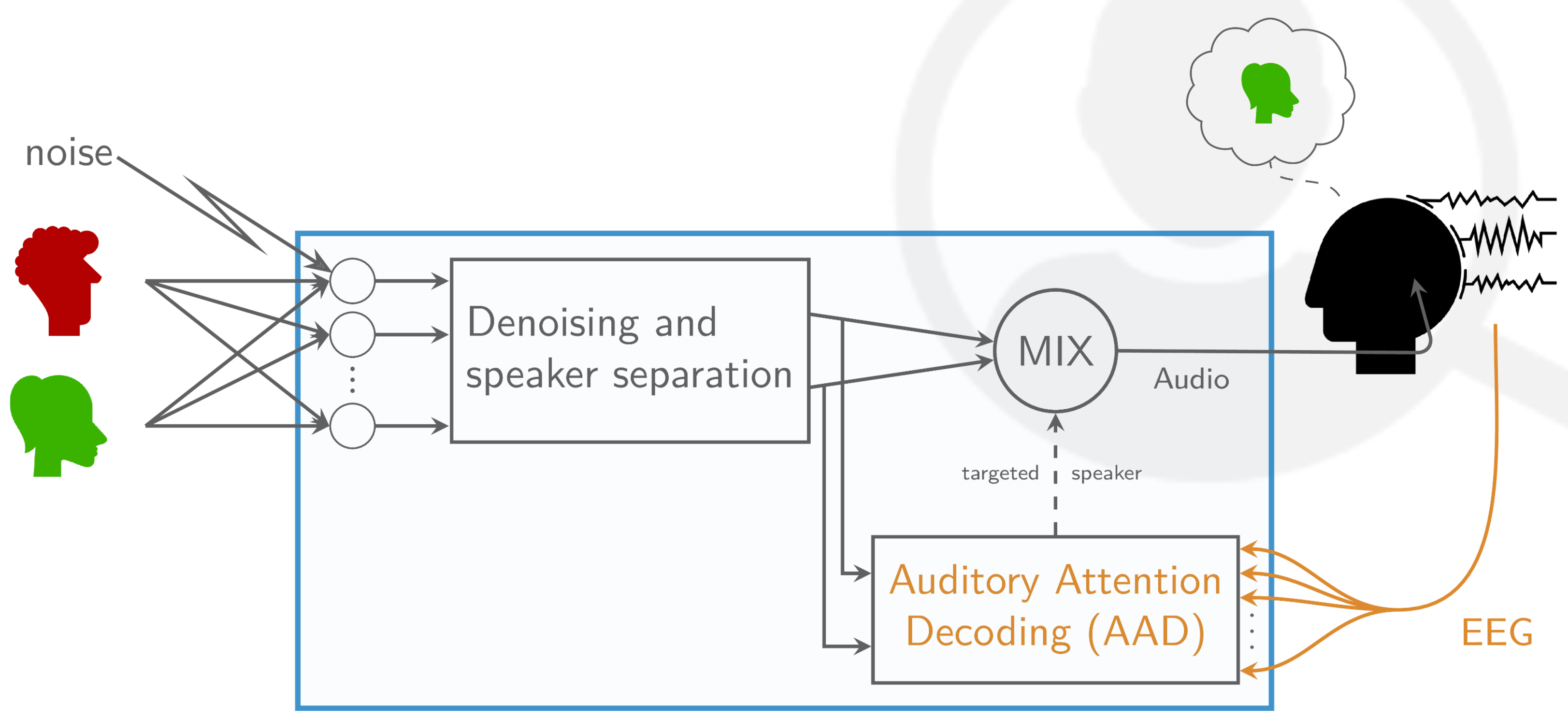
Auditory Attention Decoding

Current hearing devices fail in cocktail party scenarios as they

✗ lack information on the targeted speaker

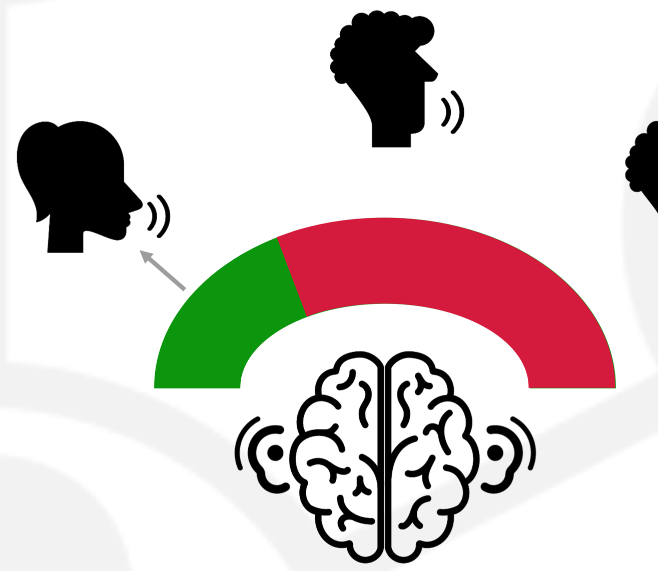
Solution

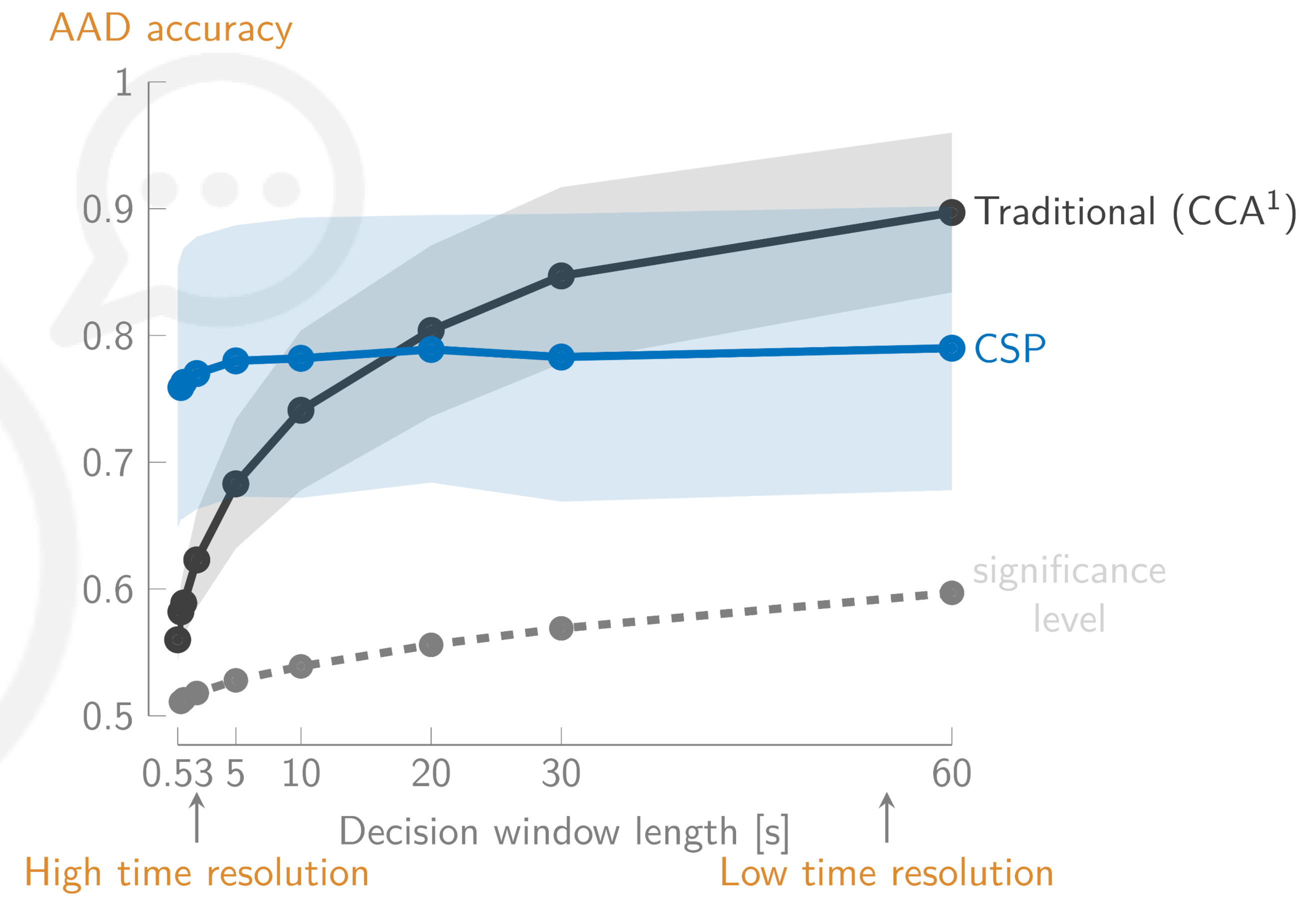
Auditory attention decoding (AAD) algorithms infer the auditory attention of the user from the electroencephalogram signal



Algorithms

Traditional AAD algorithms, which reconstruct the stimulus, suffer from an accuracy-time resolution tradeoff. An alternative is decoding the spatial focus of auditory attention using common spatial pattern (CSP) filters[2]



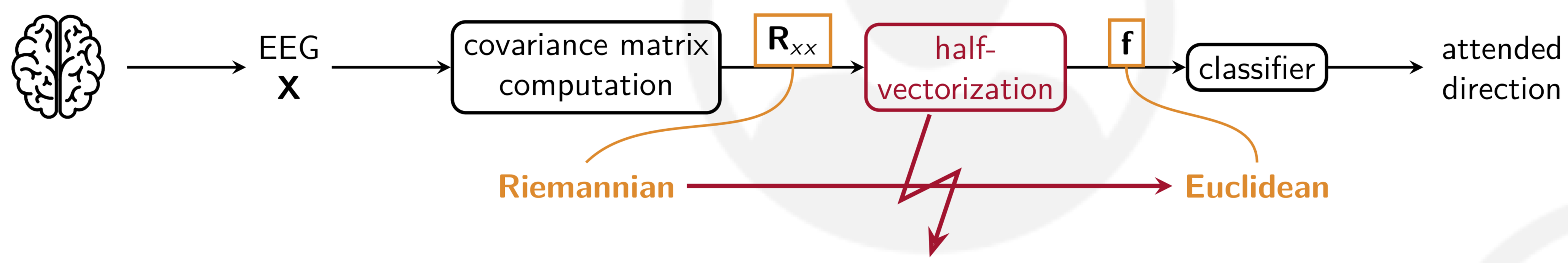


Goal

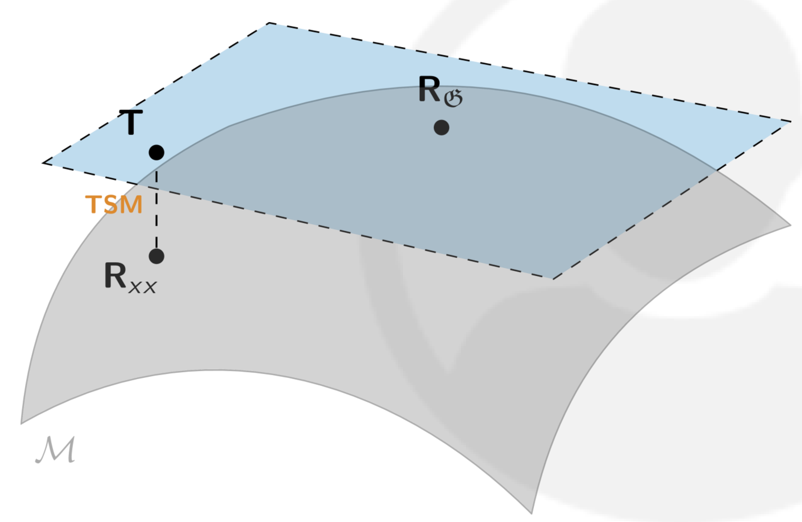
Improve on the CSP-based decoding of the spatial focus of auditory attention from the EEG using Riemannian geometry-based classifiers

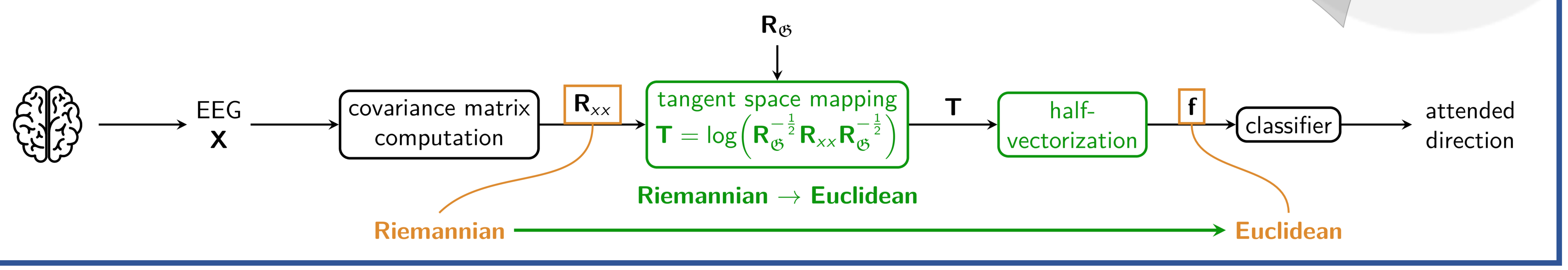
Riemannian Geometry-Based Classification (RGC)

It can be shown that – theoretically – the CSP method is implicitly classifying covariance matrices[3]. This, however, results in a **mismatch** between the differentiable Riemannian manifold on which covariance matrices live and the Euclidean space assumed by a classifier:



Given the **differentiable** Riemannian manifold, we can project each covariance matrix first on the **Euclidean tangent space** onto the Riemannian mean of the training set, in which the Euclidean distances approximate Riemannian distances between covariance matrices. This tangent space mapping ensures that classifiers can be safely applied in a Euclidean space:

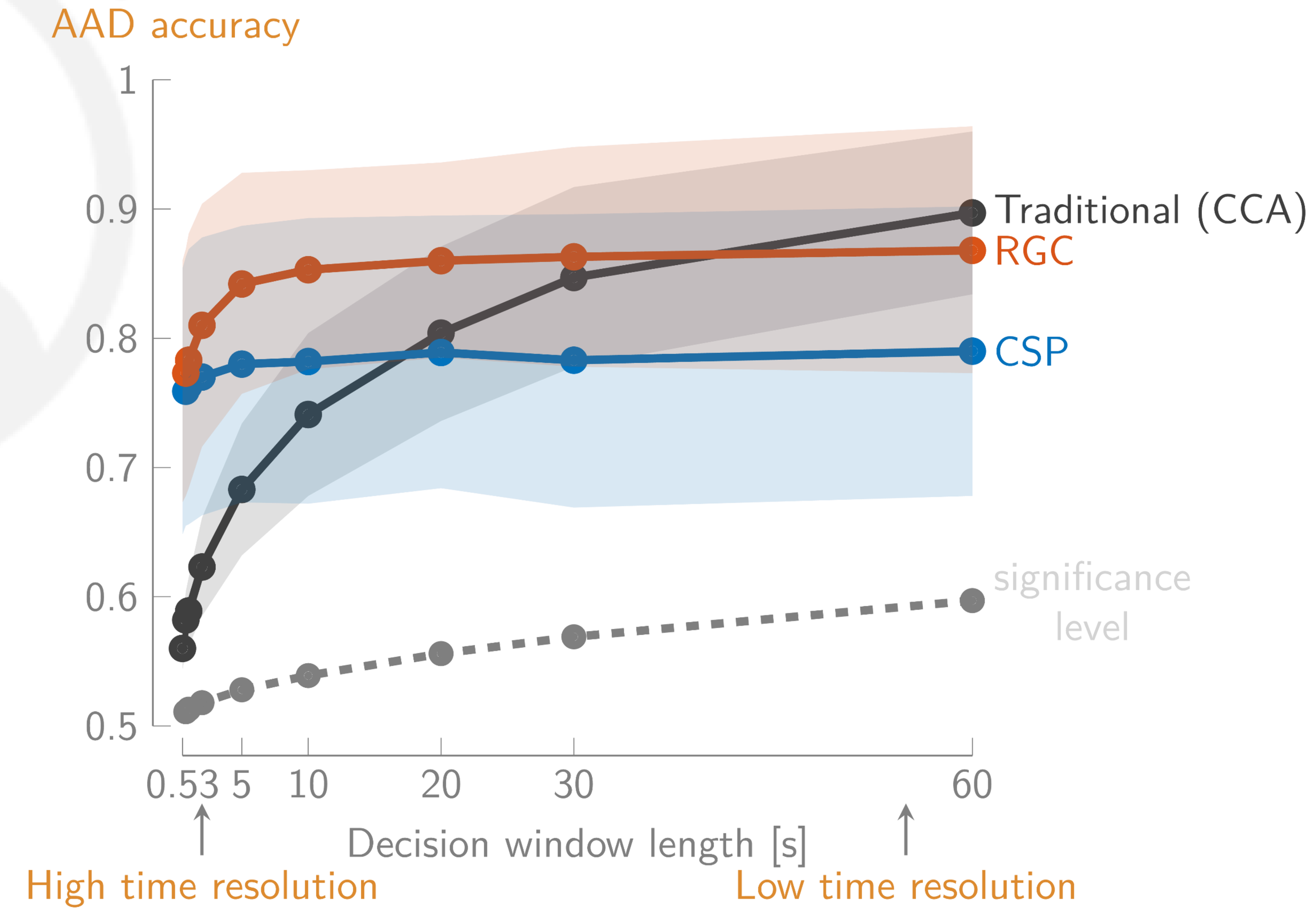




Results

The results show that:

- The RGC-based approach **outperforms** the state-of-the-art CSP method
- The RGC-based approach has **lower accuracies at high time resolution**, due to the poorer sample covariance matrix estimation
- The RGC-based approach now almost at all time resolutions **outperforms** the traditional AAD approach



[1] A. de Cheveigné, D.D.E. Wong, G. M. Di Liberto, J. Hjortkjaer, M. Slaney, and E. C. Lalor, "Decoding the auditory brain with canonical component analysis," *NeuroImage*, vol. 172, pp. 206-216, 2018

[2] S. Geirnaert, T. Francart, and A. Bertrand, "Fast EEG-based decoding of the directional focus of auditory attention using common spatial patterns," *IEEE Transactions on Biomedical Engineering*, 2020

[3] A. Barachant, S. Bonnet, M. Congedo, and C. Jutten, "Classification of covariance matrices using a Riemannian-based kernel for BCI applications," *Neurocomputing*, vol.12, pp.172–178, 2013