

Validation of EEG source reconstruction with simultaneous intracranial EEG in patients with epilepsy

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BACKGROUND

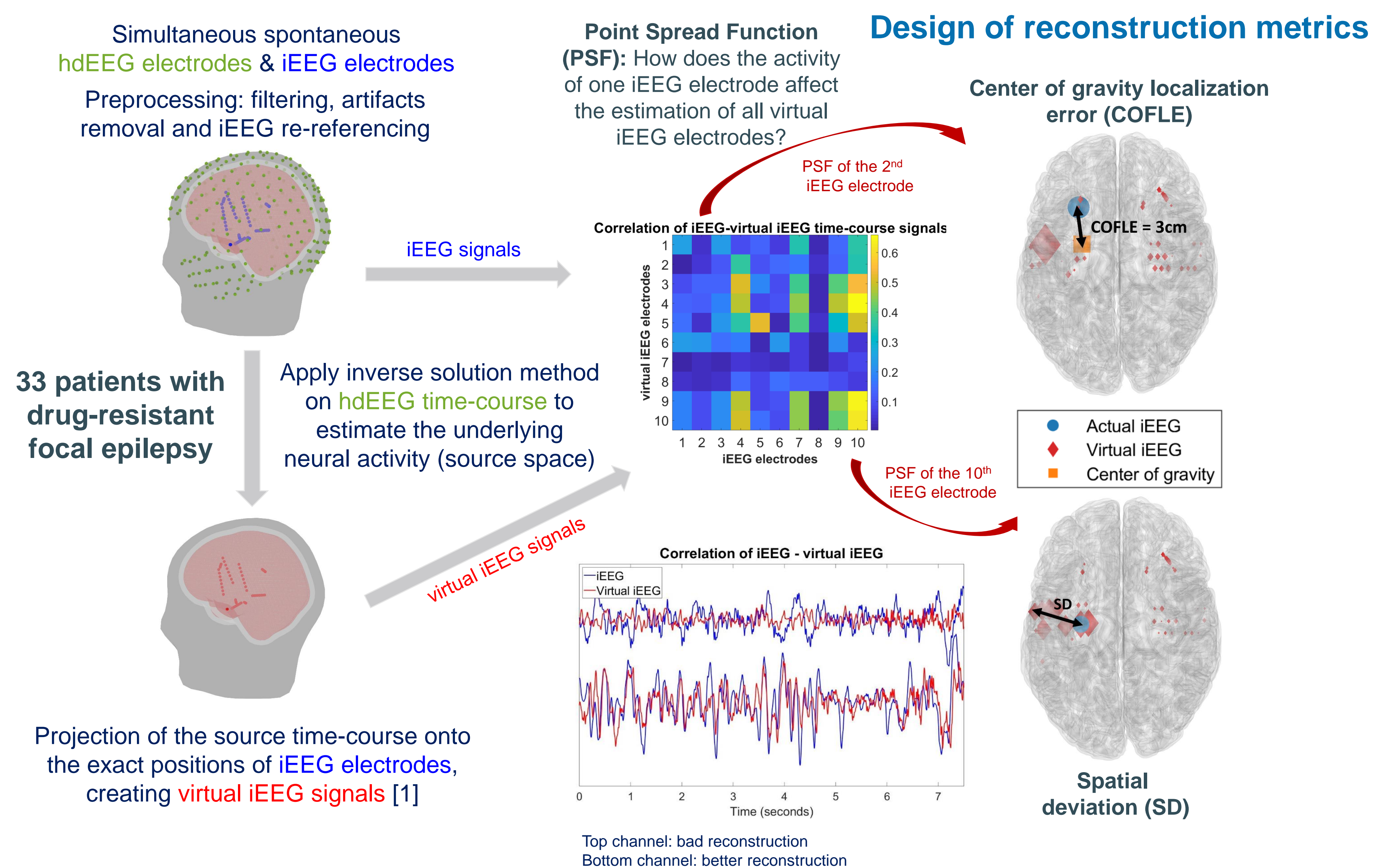
- Over 30% of the patients with epilepsy are drug-resistant.
- Epilepsy surgery is key treatment for drug-resistant cases, yet 30% of the patients still experience seizures post-surgery.
- Electroencephalogram (EEG) and intracranial EEG (iEEG) are crucial for evaluating epilepsy and for pinpointing seizure-prone areas in candidates of epilepsy surgery.
- Various inverse solution methods are used with EEG or high-density EEG (hdEEG) to detect the underlying neural activity through source reconstruction.

AIMS

- To validate hdEEG source reconstructed time-course using the gold standard of simultaneous iEEG recordings.
- To examine the effect of different inverse solution methods (eLORETA, sLORETA, wMNE) on the source reconstruction.

METHODS

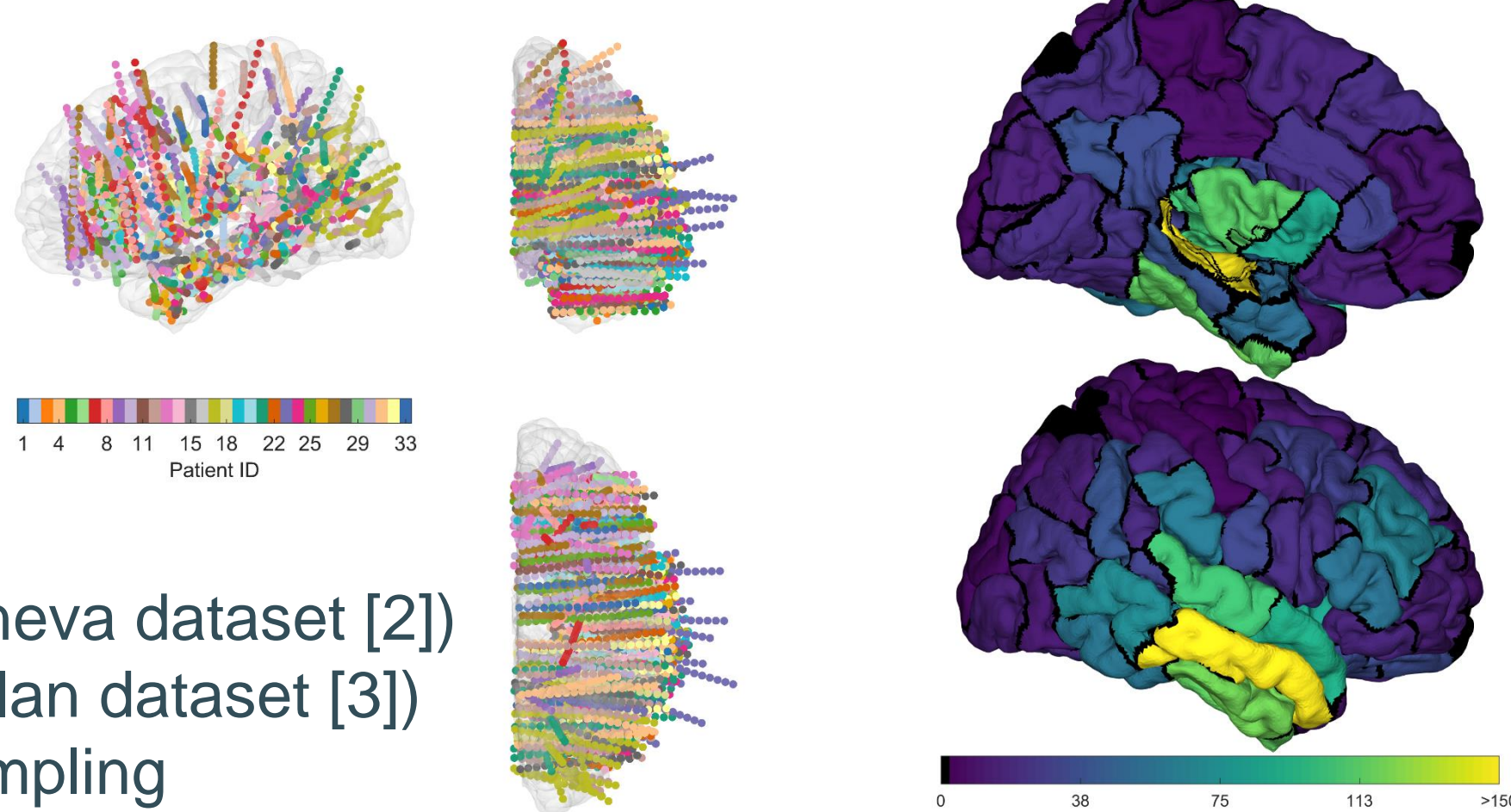
Validation pipeline for EEG source reconstruction



RESULTS

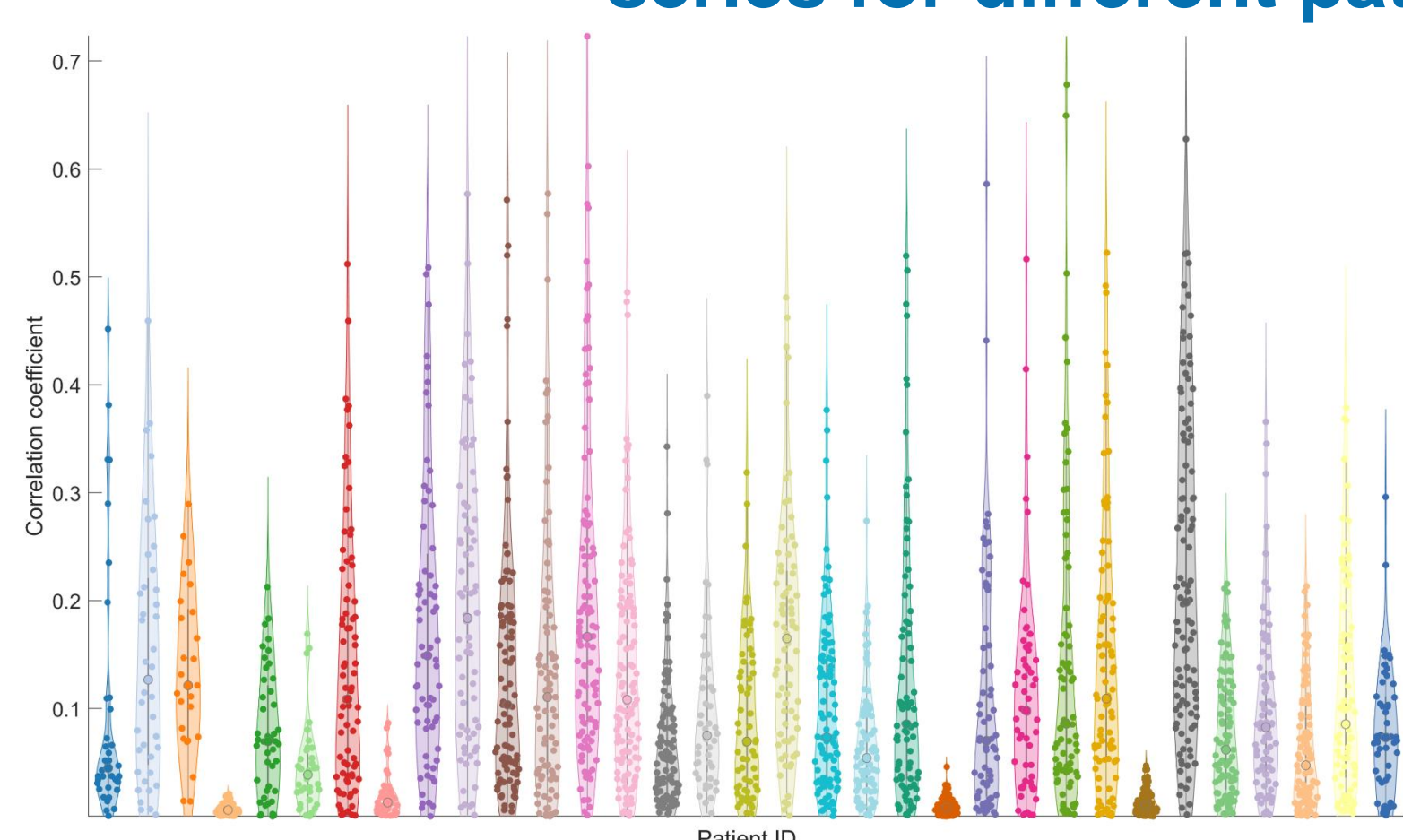
Sampling of iEEG electrodes in regions of interest

Data duration: 13 minutes (IQR: 7 minutes)



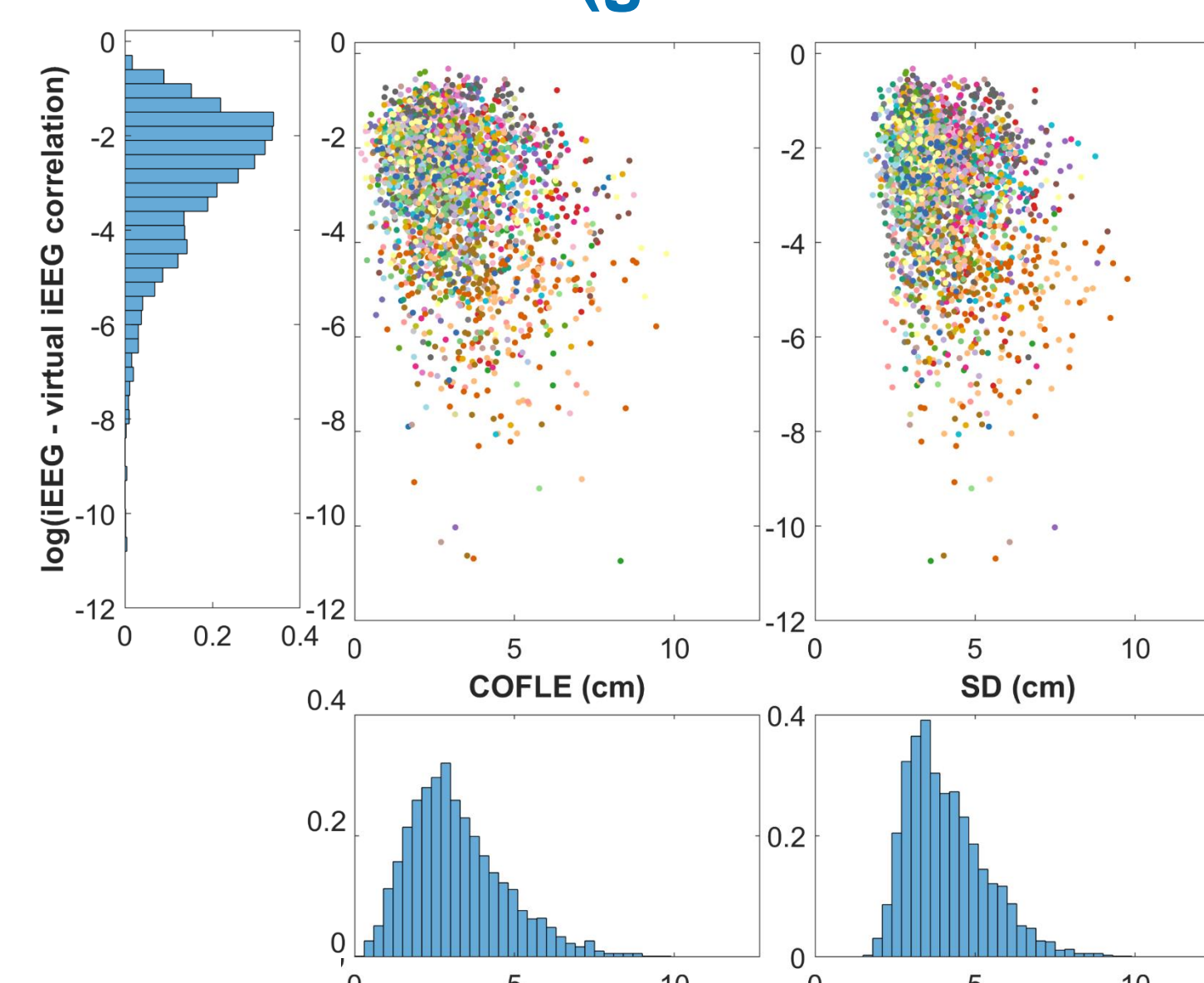
- 9 patients (Geneva dataset [2])
- 24 patients (Milan dataset [3])
- Good brain sampling

Correlation between broadband iEEG and virtual iEEG time-series for different patients



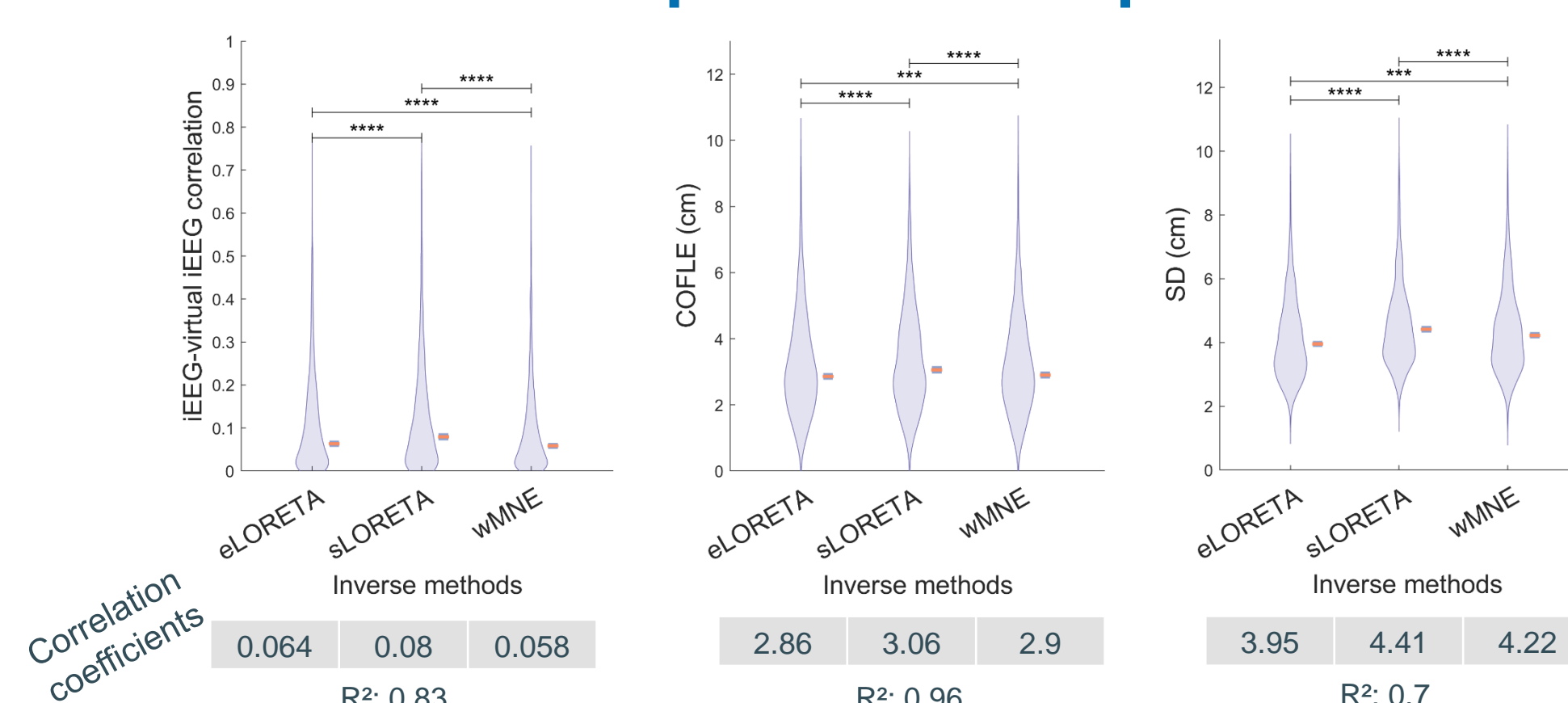
Median correlation (all patients): 0.07, [min, max] = [2.17*10⁻⁵, 0.72]

Relationship between reconstruction metrics and iEEG-virtual iEEG correlation (generalized linear mixed-effects models)



COFLE regression coefficient: -0.19 (p-value < 0.001), R²: 0.36
SD regression coefficient: -0.23 (p-value < 0.001), R²: 0.35

GLME model fit & post-hoc comparisons of inverse methods per electrodes



Reconstruction performance after post-hoc analysis (Bonferroni-corrected):

- iEEG-virtual iEEG correlation: sLORETA > eLORETA > wMNE
- COFLE & SD: eLORETA > wMNE > sLORETA

CONCLUSION

- EEG source reconstruction yields low iEEG-virtual iEEG correlation, independently of the method (eLORETA, sLORETA, wMNE), which indicates poor source reconstruction, likely due to localization errors and activity spread.
- We designed metrics to assess the reconstruction quality in terms of localization errors and activity spread, which help us compare various inverse solution methods.
- The reconstruction quality measured by the iEEG-virtual iEEG correlation is significantly better with sLORETA, while eLORETA shows significantly better performance in terms of localization errors and activity spread.
- We also intend to characterize the effects of depth, frequency and the regularization parameter on the reconstruction quality, and we will evaluate this quality using beamformers as well.

References:

- [1] Grova et al., Human Brain Mapping, 2016
[2] De Stefano et al., European Journal of Neurology, 2022
[3] Mikulan et al., Scientific Data, 2020