Enriching ConvNets with pre-cortical processing enhances alignment with human brain responses

Niklas Müller[1*] H. Steven Scholte[1,#] Iris I.A. Groen[2,#]

1. Psychology Research Institute 2. Informatics Institute

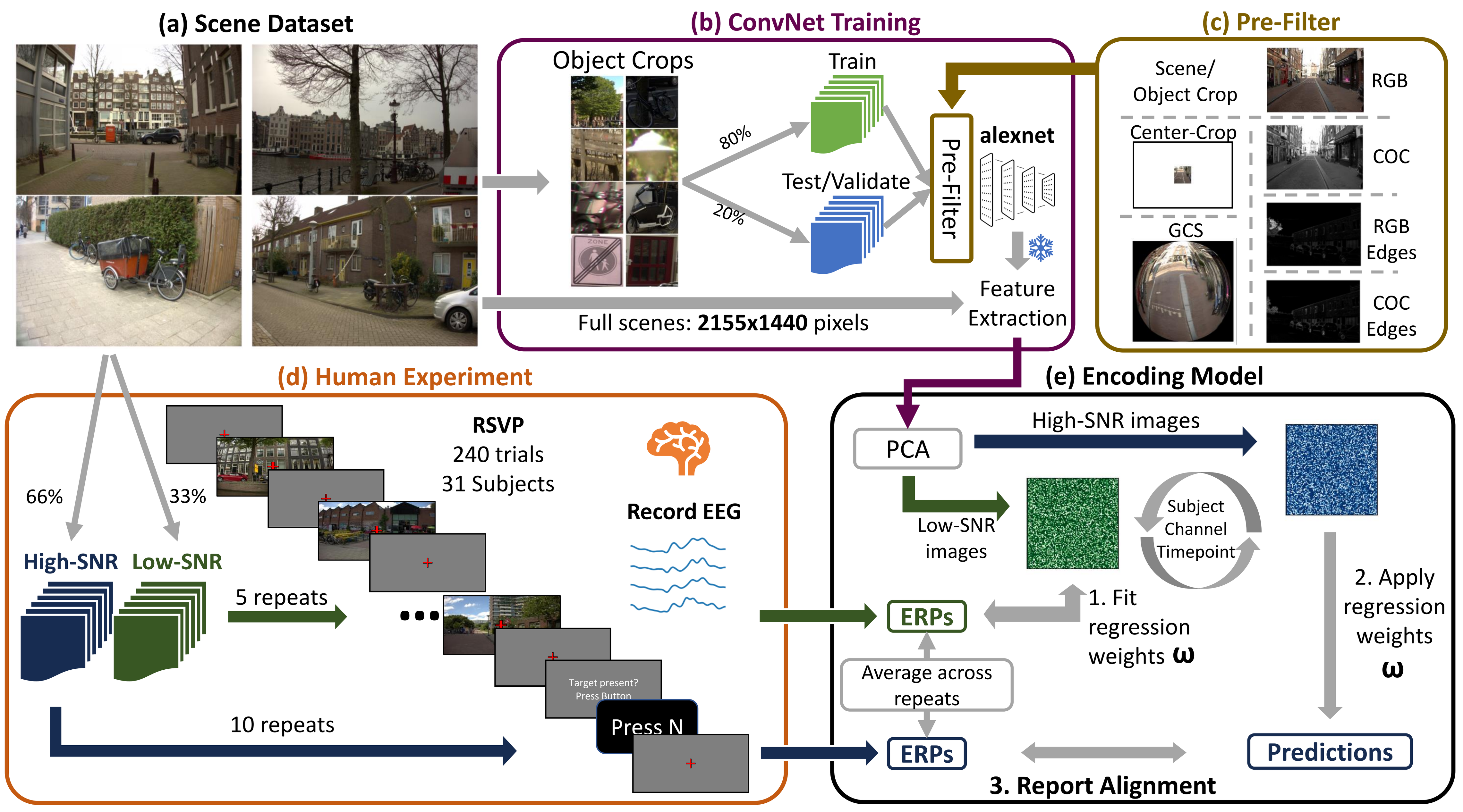
University of Amsterdam * **n.muller@uva.nl** # shared senior author

Introduction

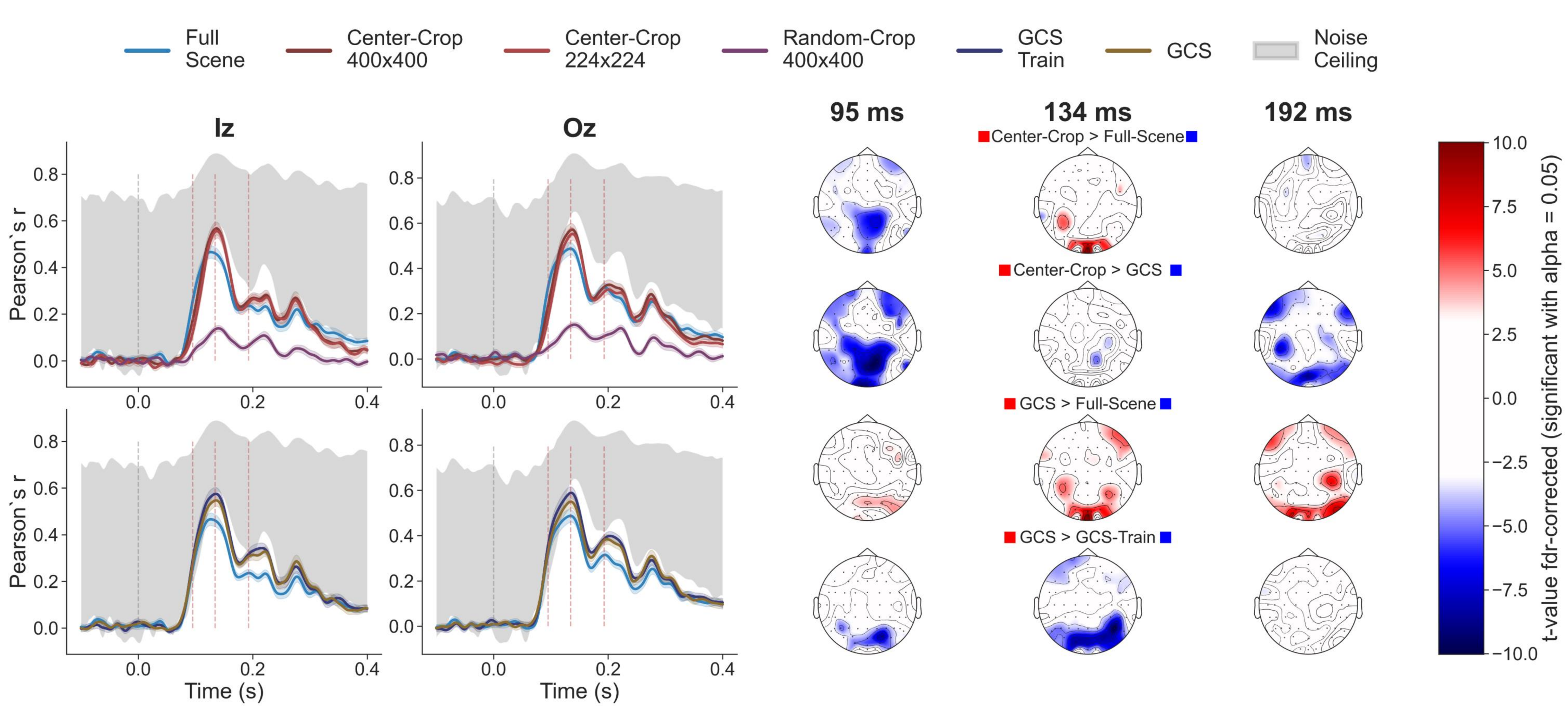
The state-of-the-art approach for predicting the neural processing underlying visual perception is building **image computable encoding models** using deep convolutional neural networks (ConvNets)[1]. Usually, the full extent of the convolutional feature maps are used for predicting brain responses.

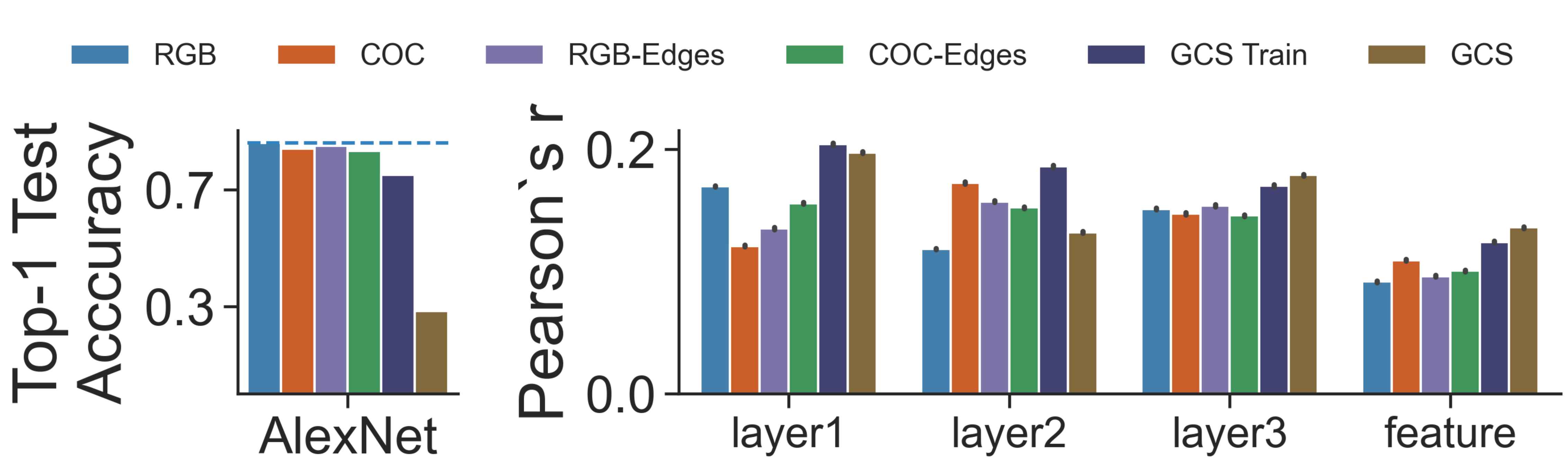
We vary the spatial weighting and the color/contrast coding of ConvNet inputs during feature extraction, inspired by human retinal processing and cortical magnification of the visual system, to improve encoding models of human EEG.

Methods



Results





- Reducing ConvNet input images to small center-crops (400x400, 224x224, or 64x64) increases predictions of EEG response amplitudes at posterior electrodes at peak time points.
- For earlier time points, using the full images yields the better prediction, as it includes the periphery which informs about the scene context.
- Applying a human retina-inspired spatial **Ganglion Cell Sampling (GCS)**[2] to ConvNet inputs yields significant prediction improvements at peak time points as well as for early time points.
- Thus, **GCS more optimally integrates and weights both central and peripheral information**.
- However, GCS shifts ConvNet inputs OOD when applied only during feature extraction (drop is top-1 test accuracy).

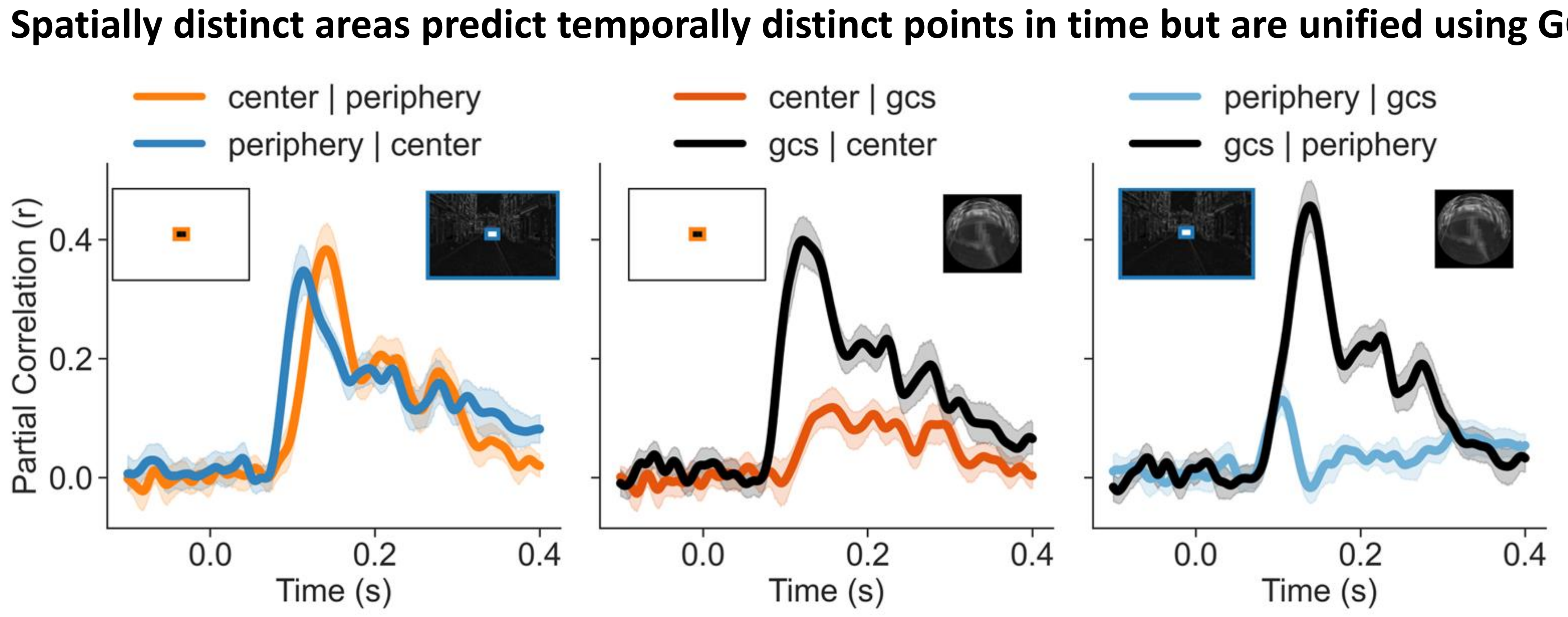
Retinal image transformation improves predictions of human EEG

Small center-crops explain substantial variance of human EEG

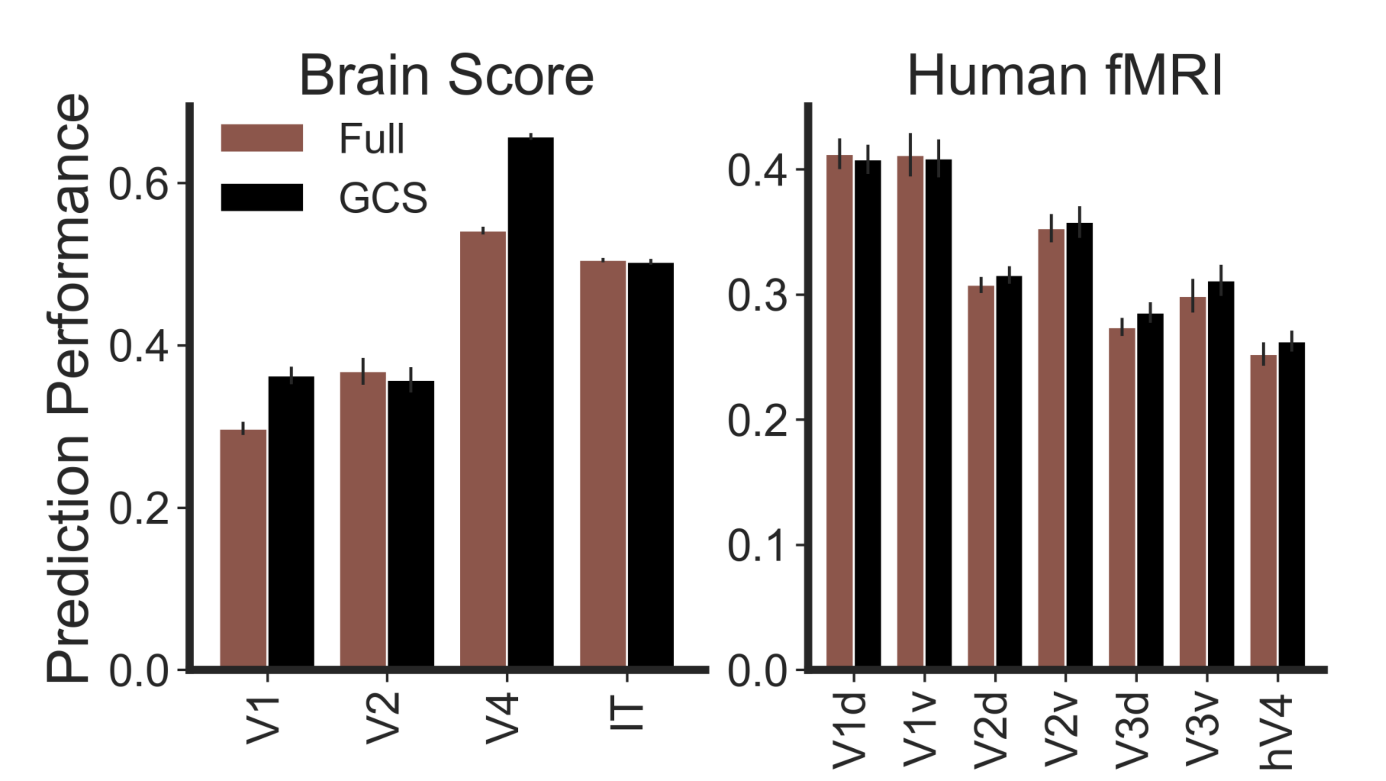
Color/contrast encodings do not improve human EEG predictions

Sneak Peak

GCS on convolutional feature maps preserves test accuracy and further improves predictions.
Spatially distinct areas predict temporally distinct points in time but are unified using GCS.



GCS improves neural predictions of monkey electrophysiology and human fMRI.



Acknowledgements | This work was funded by the UvA Data Science Center

References | [1] Naselaris et al. *Neuroimage*, 2011; [2] da Costa et al. *Sci. Rep.*, 2024.