Ultra-high resolution images improve modeling of neural activity evoked by natural scenes

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DSC

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Modeling Visual Human-EEG

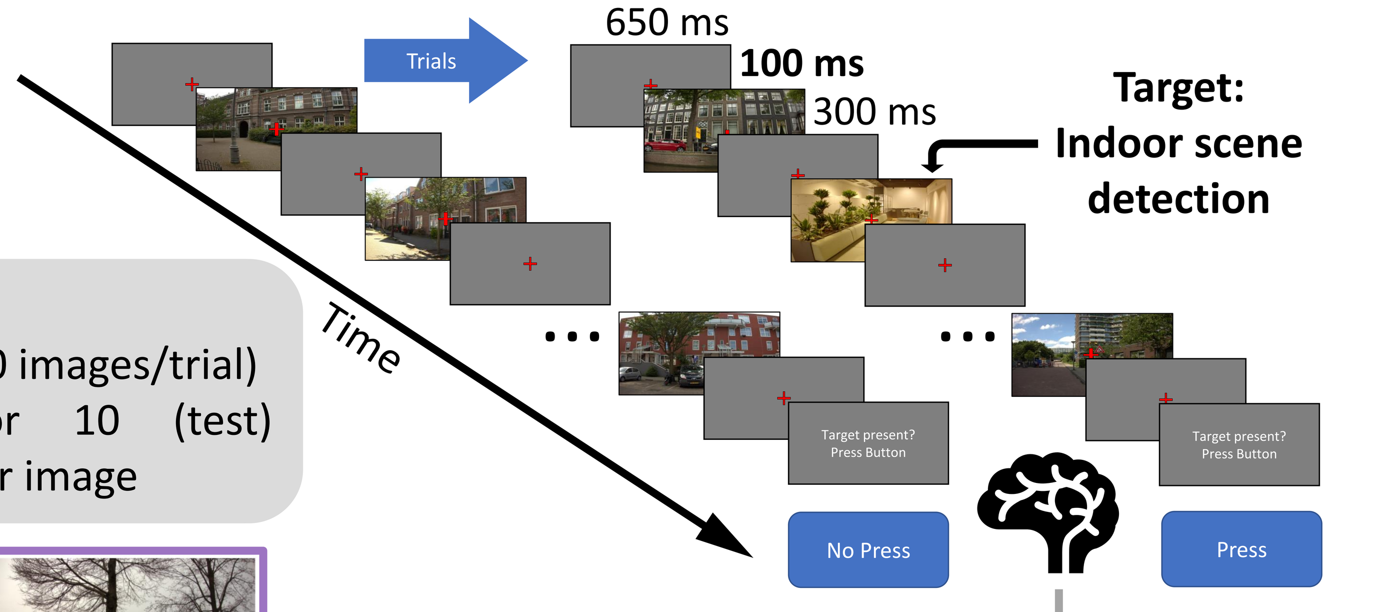
A particular approach to better understanding visual perception is building **image-computable encoding models** of brain responses [1, 2]. Many studies use small and limited-quality image when studying visual perception. It remains unclear whether high-quality images are needed for modeling of information processing in the visual cortex. The degree to which image details are reflected in neuroimaging data, especially EEG-recordings, is unknown. Using **ultra-high-resolution images** we investigate the sensitivity to image quality of computational models explaining human-EEG data.

We find that reducing local image detail when modeling ERP-responses linearly decreases prediction performances. Further, ERP-responses are better explained with high local detail and using information from the center rather than from the periphery.

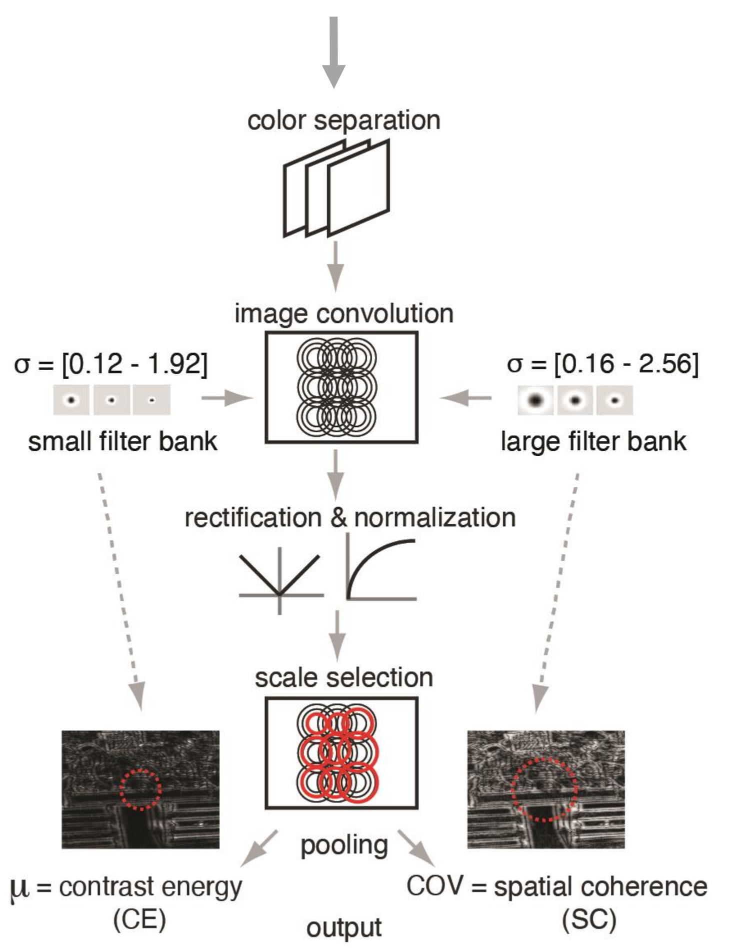
Open Amsterdam Data Set (OADS)

We collected EEG-data from human participants in a **RSVP** experiment using high-resolution (**2155x1440 pixels,** 25° visual angle radius) scene images from the **Open Amsterdam Data Set (OADS)**.

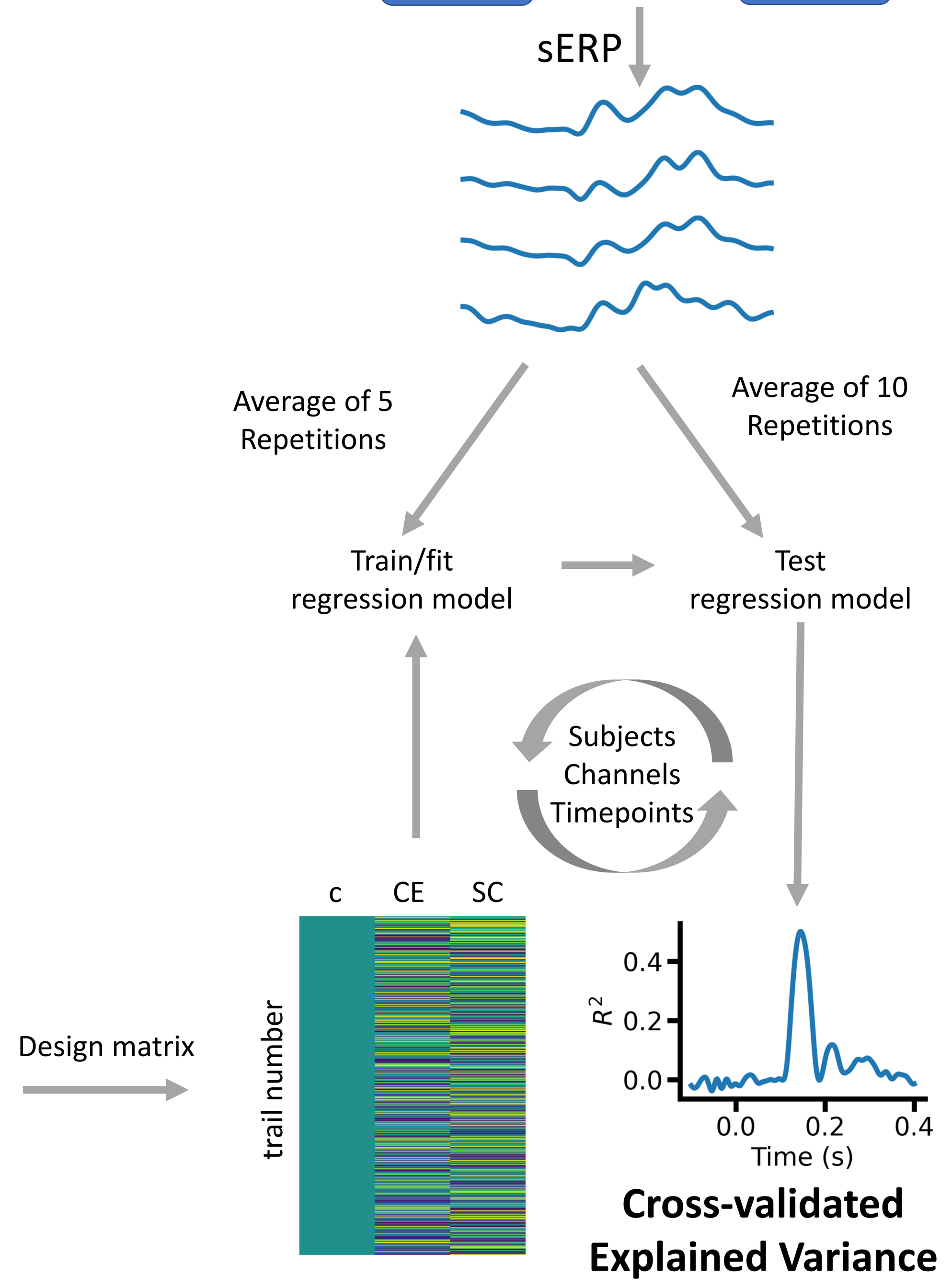
OADS
- 6130 Scene images
- 5496x3672 pixels



- 31 Subjects
- 3840 Trials (20 images/trial)
- 5 (train) or 10 (test) repetitions per image



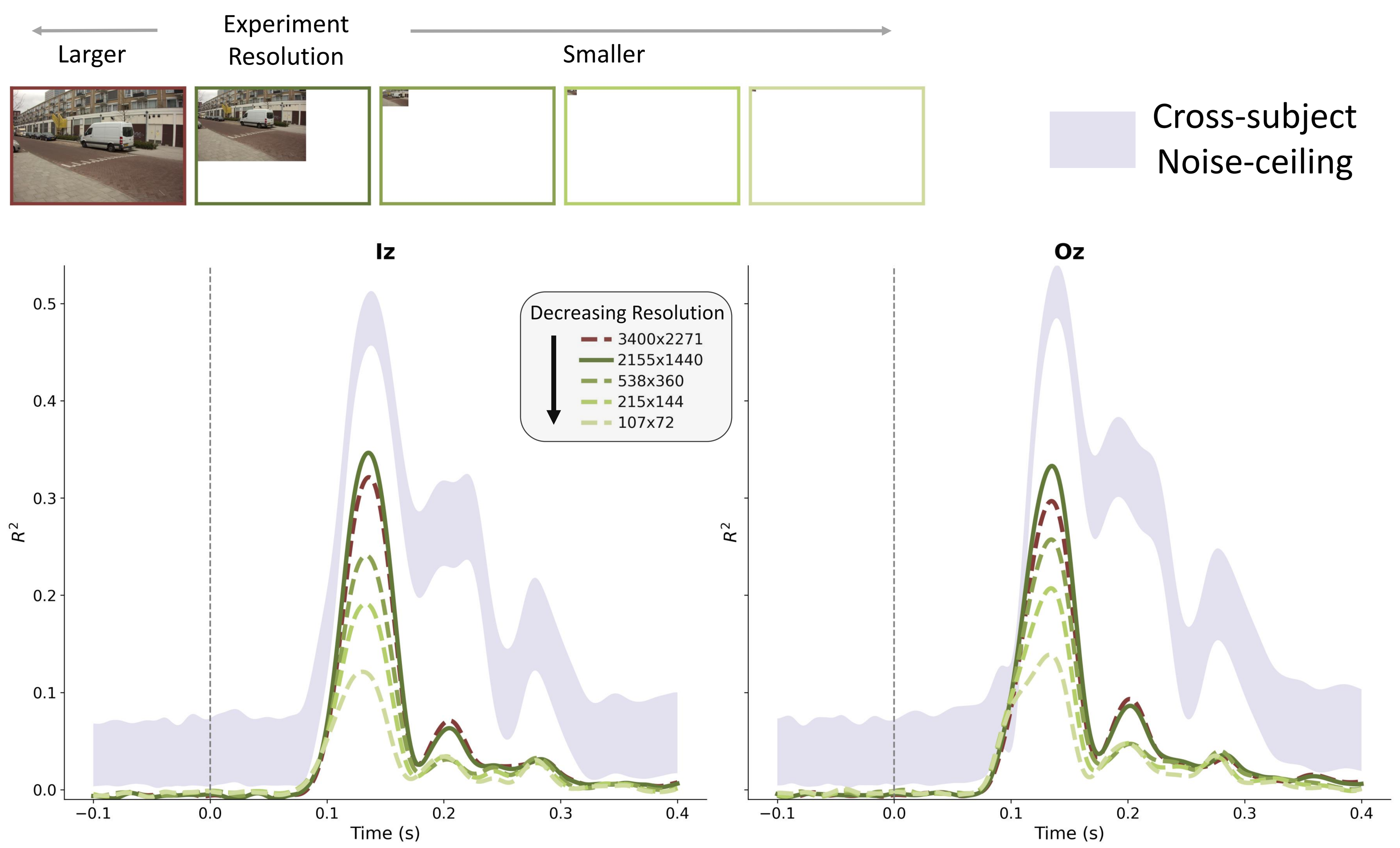
Scene Statistics Model [3]



Linear Regression Model

Modeling using high-resolution images

To measure the importance of using **high resolution images**, we compute CE/SC for multiple image resolutions and linearly fit these to the ERP-response per subject, electrode, and timepoint and evaluate each regression model using **cross-validation**. Additionally, we model the maximally explainable variance by linearly regressing the average response onto the induvial response per subject: **Cross-subject noise ceiling**

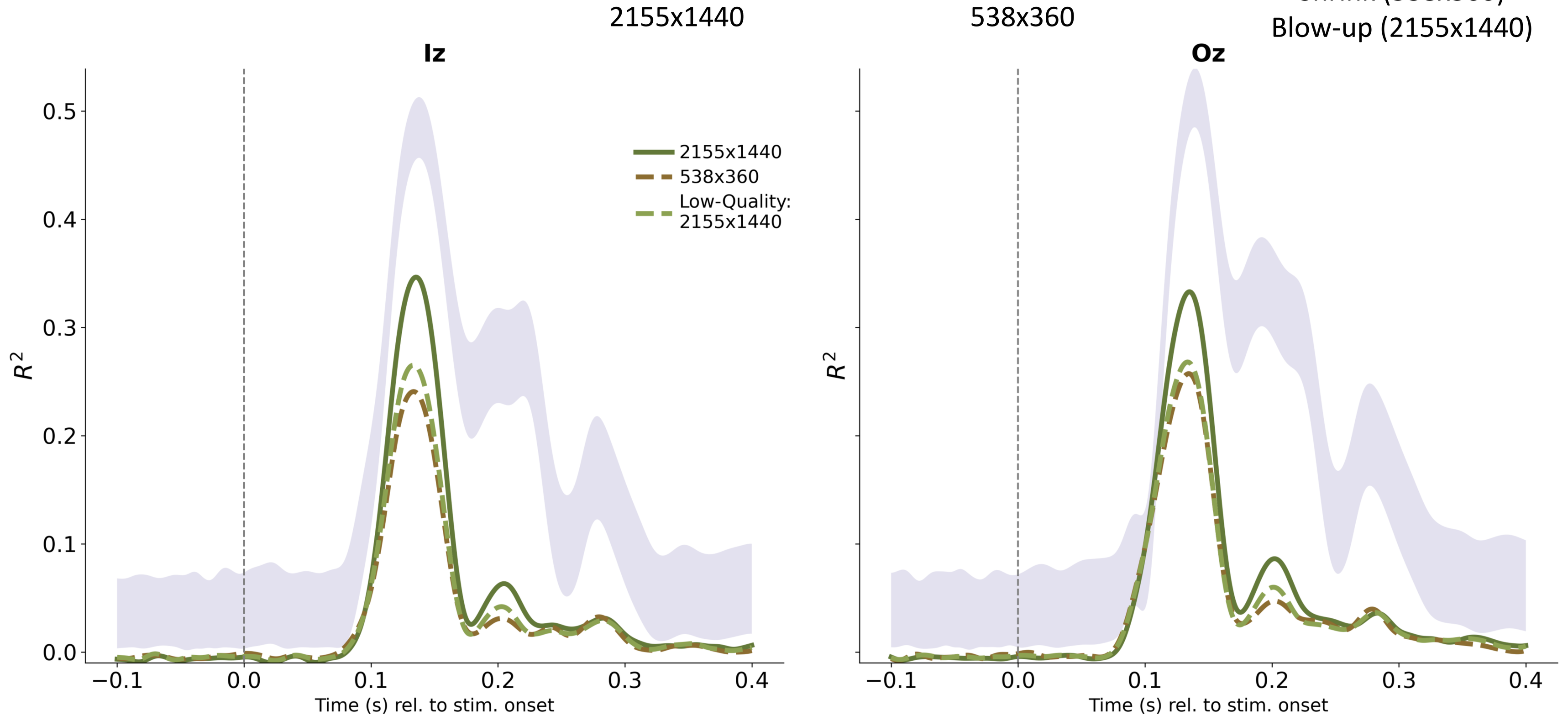


Decreasing (or increasing) image resolution decreases EEG explained variance. Human perceptual limit reached above 2155x1440.

Image extent vs. Image quality

Images with a high resolution can still have a low quality (e.g., because of compression). Compressed images are often used in computational modeling, as they reduce computational overhead. To discern whether modeling human ERP-response benefits from increasing image extent or image quality, we compute CE/SC on high resolution images, low resolution images, and images with high resolution but low quality.

2155x1440 | 538x360 | Shrink (538x360) Blow-up (2155x1440)



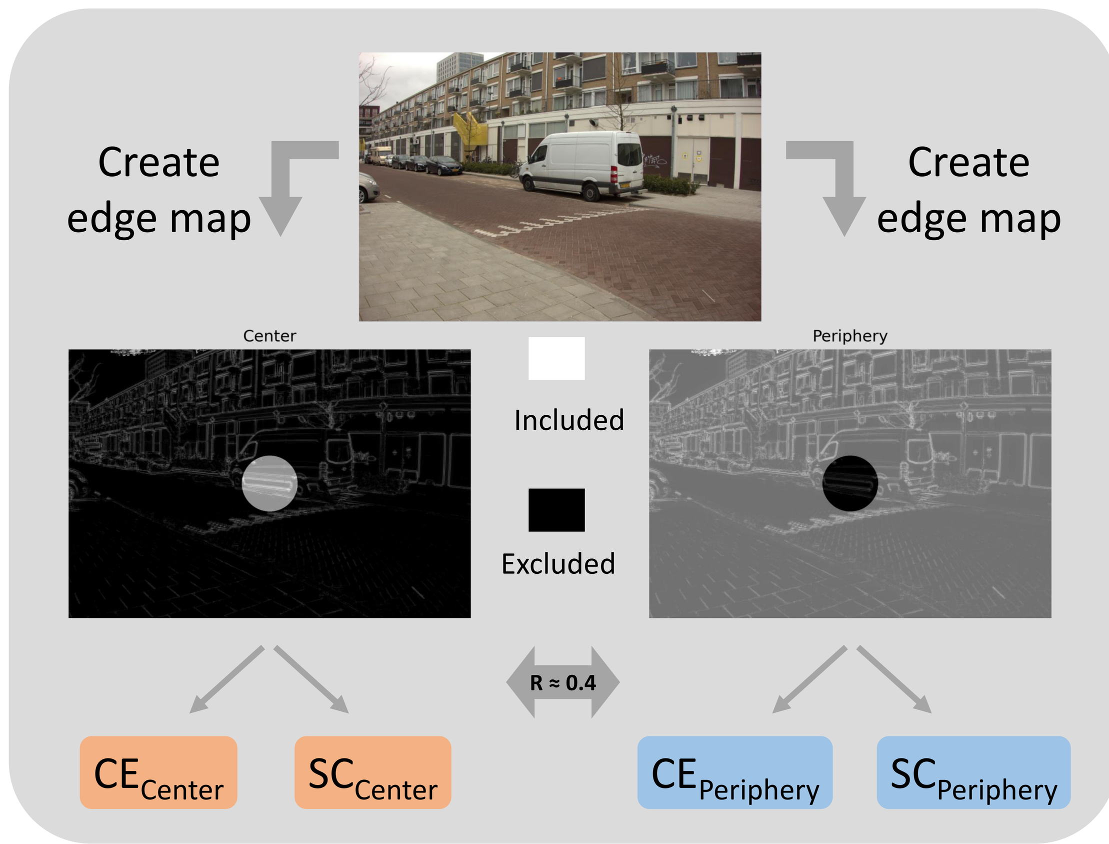
Decrease in EEG explained variance results from decrease in local detail, not from decrease in image extent.

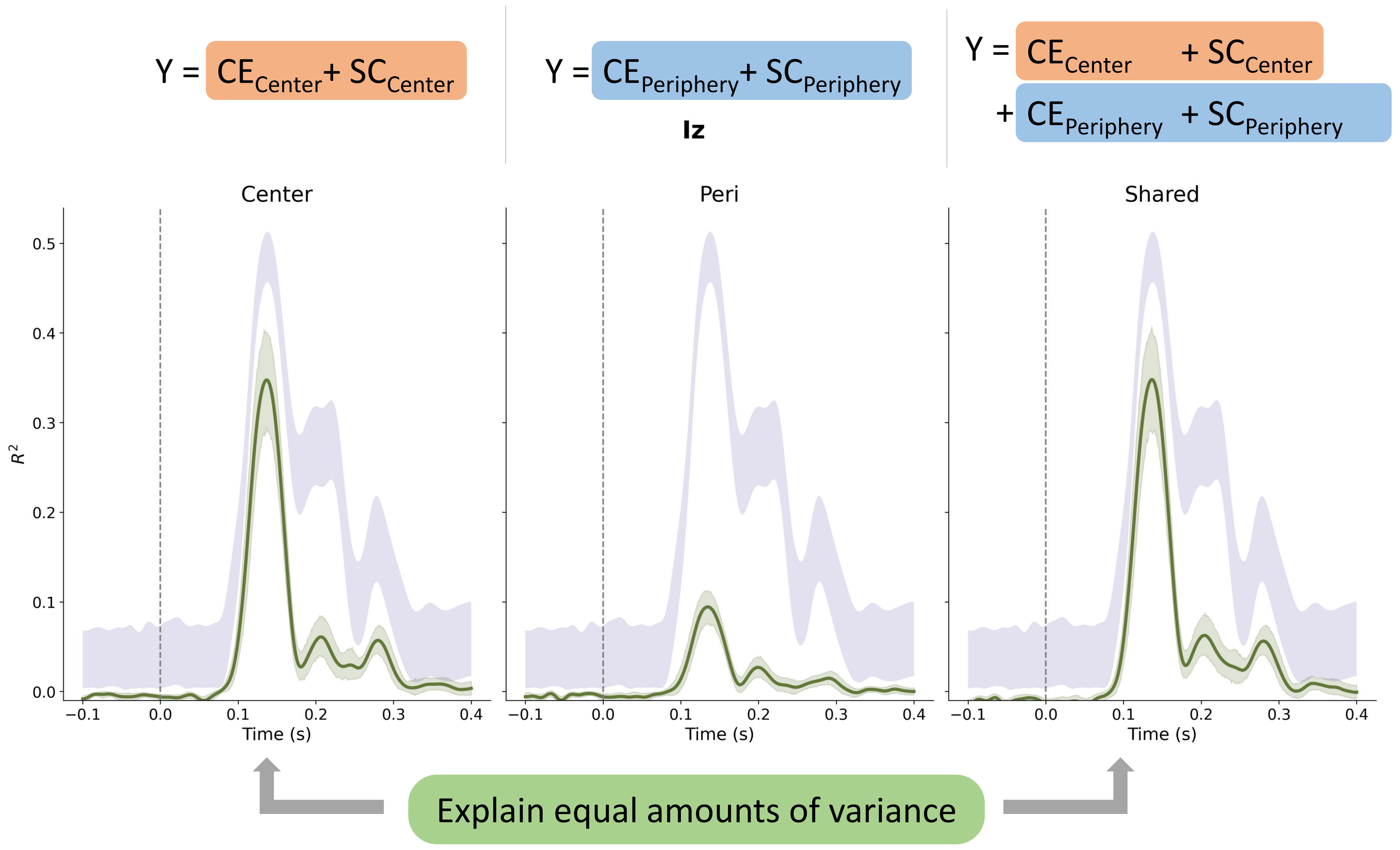
Center resolution drives explained variance

The **human retina samples with high resolution** around the **central gaze region** and with gradually decreasing resolution towards the periphery.

Our model reflects this by computing CE on a small region around the center and SC on a larger region around the center.

To inspect whether this sampling is adequate for modeling ERP-responses to high resolution images we fit separate models using the following regressors. "Y" refers to the ERP-response.





Modeling ERP-responses using statistics from the center only explains as much variance as including regressors for peripheral statistics

Conclusions

- Modeling using high quality images explains ERP-responses best: decreasing quality decreases fit.
- However, improvement of fit by increasing resolution seems to be limited by perceptual saturation:
  - for humans, a resolution of 2155x1440 is perceptually equivalent to 3400x2271
- ERP responses for posterior electrodes are dominated by foveal image statistics
  - Goodness of fit exclusively depends on inclusion of foveal regions
- **Improved spatial sampling** particularly of the periphery needs to be incorporated to improve model fit and potentially explain remaining amount of explainable variance.

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References | [1] Naselaris et al. *Neuroimage,* 2011; [2] van Gerven *J. of Math. Psy. (2017);* [3] Groen et al., *J. of Neurosci.*, 2013.