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Voxel-Wise Predictive Encoding Models Reveal Evidence for Pre-Saccadic Remapping in the Human Visual Cortex

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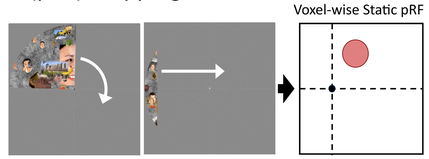
INTRODUCTION

- Saccades drastically shift retinal visual inputs.
- Receptive fields (RFs) of visual neurons in non-human primates are remapped toward new spatial locations in anticipation of saccade[1,2,3]. (e.g., Forward remapping, Convergent remapping)
- However, questions remain regarding the cortical distribution of remapping, the distinct forms it may take, and whether analogous mechanisms exist in the human visual system.

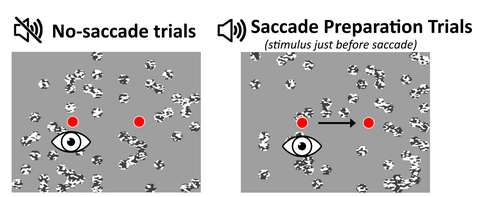
Here we apply an innovative fMRI voxel-wise encoding model approach to study pre-saccadic remapping across the human visual system

METHODS (N=8)

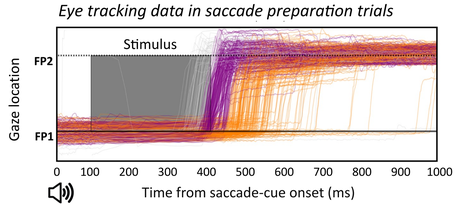
- fMRI Population Receptive Field (pRF) Mapping session



- fMRI Main Experiment session

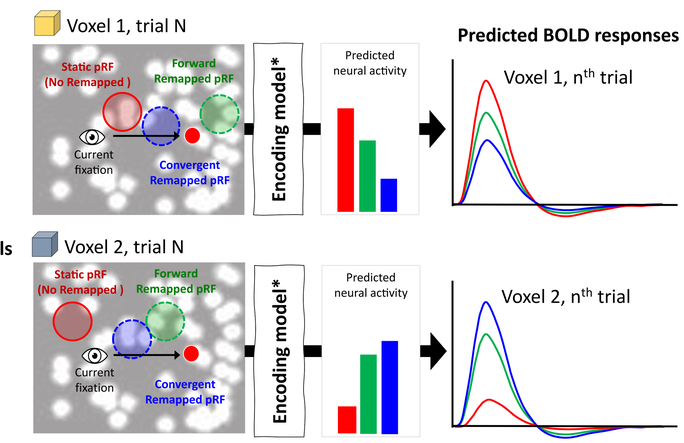


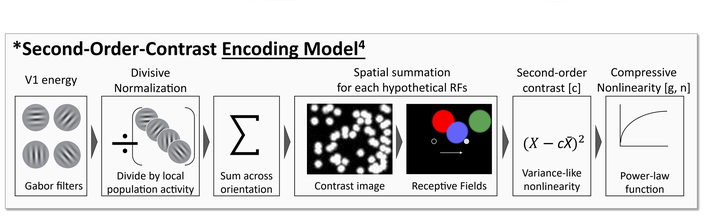
Eye tracking data in saccade preparation trials



Voxel-Wise Encoding Model

- Unique hypothetical encoding models were used to predict neural responses evoked by visual stimuli presented in each trial in main experiment.

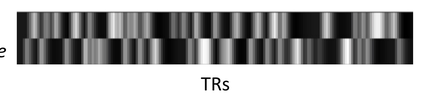




Encoding Model Validation

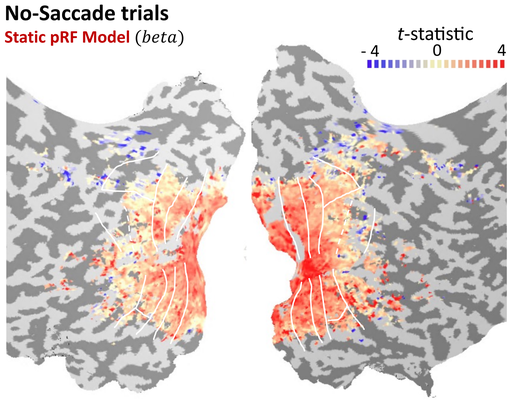
- **Measured** BOLD responses for each voxel in main experiment session

- **Predicted** BOLD responses for each voxel (from encoding models):
  Static *or* ***Forward*** *or* ***Convergent*** *Remapped Models*

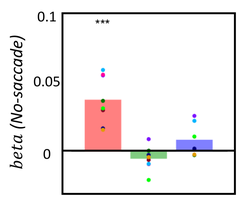


Ridge Regression (r^2, Beta coefficients)

No-Saccade trials
Static pRF Model $(beta)$

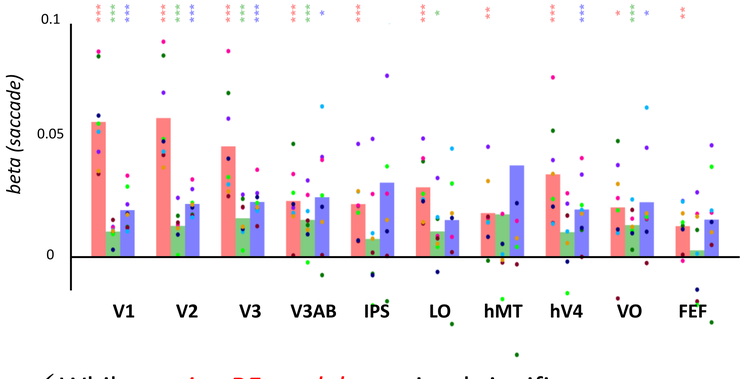


✓ Without upcoming saccade, stimulus-evoked activity is predicted by static pRF model, not forward or convergent remapping models

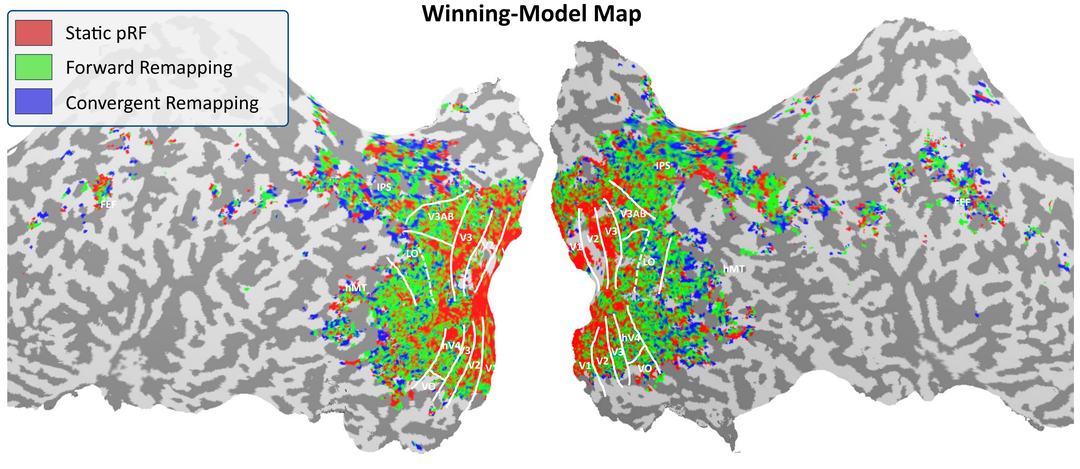


RESULTS: Pre-saccadic Remapping

- Compare encoding models for ***Static*** *vs* ***Forward*** *vs* ***Convergent***
  - No-saccade trials: always fixed to *Static pRF Model*
  - **Saccade Preparation trials** (selected based on eye-tracking):
    - *Which remapping model best explains the observed data?*



✓ While *static pRF model* remained significant across most visual ROIs, the fits decreased in later visual areas, where *Forward* and *Convergent remapping models* also predicted neural activity evoked by visual stimulus flashed during saccade preparation.



✓ Cortical projection of voxel-wise winning models (best r^2) showed early visual areas best explained by *static pRF model*, while *forward* or *convergent* remapped models emerged as a dominating model in later visual areas.

✓ Our voxel-wise predictive encoding model approach additionally enables testing of: (1) flexible spatial forms of remapping, (2) their temporal dynamics, and (3) relationship to voxel-wise functional properties (e.g., connectivity, pRF profiles).

CONCLUSIONS

- Our fMRI predictive encoding model approach provides a cortex-wide, voxel-resolved view of pre-saccadic remapping in the human visual system.
- Replicating evidence from electrophysiology, we observed pre-saccadic RF remapping in higher-level visual areas.
- The current study demonstrates how distinct forms of remapping might coexist and tradeoff in different regions.
- Together, this work bridges primate electrophysiology and non-invasive human neuroimaging, advancing our understanding of the neural mechanisms that support visual stability across saccades.

REFERENCES

[1] Duhamel et al. (1992). The updating of the representation of visual space in parietal cortex by intended eye movements. *Science*, *255*(5040), 90-92.
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[3] Golomb, J. D., & Mazer, J. A. (2021). Visual remapping. *Annual review of vision science*, *7*(1), 257-277.
[4] Kay et al. (2013). A two-stage cascade model of BOLD responses in human visual cortex. *PLoS computational biology*, *9*(5), e1003079.