Selective Functional Connectivity between Ocular Dominance Columns in the Primary Visual Cortex

Iman Aganj and **Shahin Nasr**

Athinoula A. Martinos Center for Biomedical Imaging
Massachusetts General Hospital
Harvard Medical School

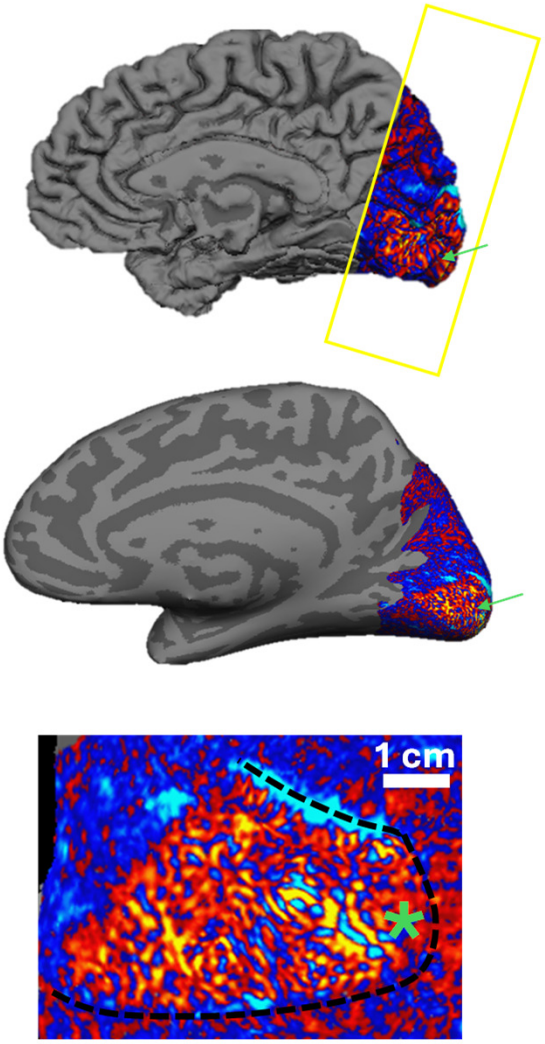
Why: The primary visual cortex (V1) in humans and many animals is comprised of fine-scale neuronal ensembles that respond preferentially to the stimulation of one eye over the other, also known as the ocular dominance columns (ODCs). Despite its importance in shaping our perception, to date, the nature of the functional interactions between ODCs has remained poorly understood. In this work, we aimed to improve our understanding of the interaction mechanisms between fine-scale neuronal structures distributed within V1.

What: We applied high-resolution functional MRI to study mechanisms of resting-state functional connectivity (rs-FC) between ODCs. Using this technique, we quantified the level of functional connectivity between ODCs as a function of the ocular preference of ODCs.

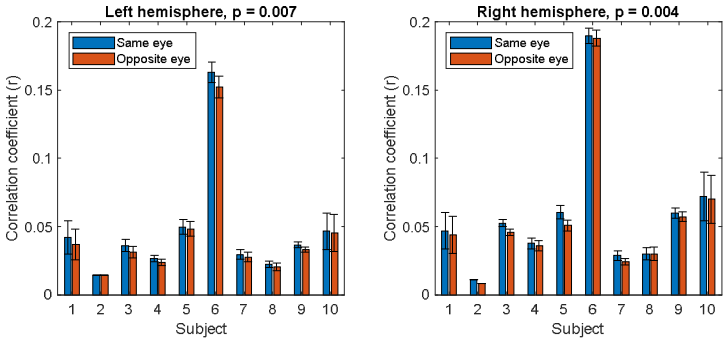
How: 10 participants (25-45 years old) were included, who were scanned at 7T for stimulus-based ODC localization and rs-FC measurement (while defining the V1 border retinotopically), and at 3T for structural imaging. Functional data were projected to the FreeSurfer-computed cortical surface, and partial correlation coefficients of the resting-state data were computed for vertex pairs in V1. Selectivity of rs-FC was inferred by comparing the rs-FC between vertices with *alike* vs. *unalike* ocular preference, both in the entire V1 and in separate ODC distance quantiles. Next, we tested the reproducibility of rs-FC selectivity by comparing it in two different-day sessions for two subjects, while also assessing how machine-learning approaches predicted the ODC map from the rs-FC patterns.

Results: ODCs with *alike* ocular preference were more strongly interconnected than those with *unalike* preference, even at long distances. The selective trend of rs-FC remained consistent from day to day. Machine-learning (ensemble of learners with bootstrap aggregation) predicted ODC beta maps correlated with the ground truth (r=0.15±0.02).

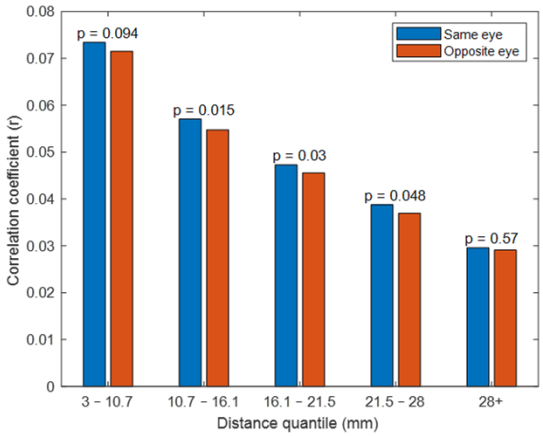
Conclusion: We used the well-studied functional organization of ODCs to test the capabilities of rs-FC in human subjects to reveal the mesoscale functional organization of the human visual cortex. Our results, when combined with findings in animals, can help to fill the gap in our knowledge of rs-FC between ODCs in humans as compared to animals.



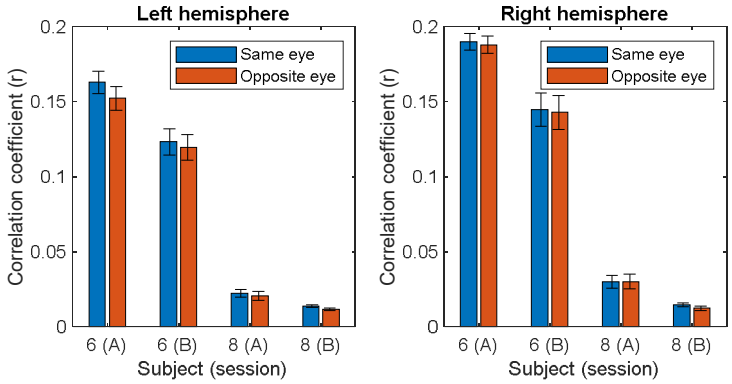
ODC maps were made by contrasting the response to left vs. right eye stimulation. Here they are overlaid on the pial (top), inflated (middle), and flattened (bottom) representations of a subject's cortex. The green arrow and asterisk indicate the foveal direction. The black dashed line (bottom) shows the borders of V1, defined retinotopically.



The level of rs-FC between ODCs with *alike* (same eye) vs. *unalike* (opposite eye) ocular preference, averaged across runs for each subject and hemisphere (error bars: standard error of the mean). Paired *t*-test across subjects in each hemisphere revealed mean rs-FC to be significantly higher between vertices with *alike* rather than *unalike* ocular preference.



The level of rs-FC between ODCs with same (*alike*) vs. opposite (*unalike*) ocular preference, averaged across hemispheres and subjects, for different distance brackets. Paired *t*-tests are across subjects (hemispheres averaged).



Reproducibility of rs-FC selectivity between ODCs across two scan sessions (A & B) for two subjects (6 & 8).

NIH National Eye Institute
NIH National Institute on Aging