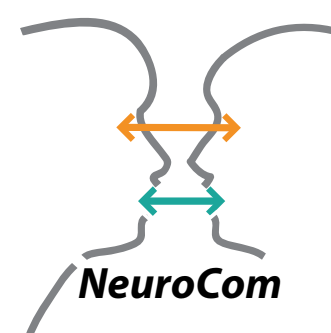# Reliable mapping of columnar structures in early visual cortex using GE-EPI at 7 T

Daniel Haenelt[1,2], Robert Trampel[1], Roland Mueller[1], Shahin Nasr[3,4], Jonathan Polimeni[3,4], Roger Tootell[3,4], Martin Sereno[5], Nikolaus Weiskopf[1]

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Introduction

- At ultra-high magnetic fields (≥ 7 T), fMRI enables the delineation of mesoscale human functional structures.
- However, when using GE-EPI, the activation pattern may suffer from the well-known bias due to draining veins, especially close to the pial surface. [1]
- Measurement of functionally-based fine structures with known shape like ocular dominance columns (ODCs) in V1 and stripes in V2 allows quantification of depth-dependent vascular blurring inherent to GE-EPI and other sequences.

Objectives

- Assessment of repeatability in measuring ODCs and thin stripes using GE-EPI.
- Direct visualization of hemodynamic blurring across cortical depth.

Methods

Experimental design

- Two participants were invited for either ODC or color-selective thin stripe mapping and were scanned multiple times on different days.
- ODC: Alternate stimulation of single eyes using red/green moving random dots viewed through anaglyph goggles. [2]
- Thin stripes: Stimulation of both eyes with either moving chromatic (red/blue) or achromatic gratings. [2]

MRI data acquisition

- 7 T whole-body MR scanner (MAGNETOM 7T, Siemens Healthineers, Erlangen, Germany).
- 32 channel phased array head coil (NOVA Medical Inc., Wilmington MA, USA).
- ODCs were measured with either isotropic 0.8 mm or 1.0 mm resolution whereas thin stripes only with 1.0 mm.
- 2D GE-EPI was used with coverage of early visual areas; ODC: TR = 2 s/3 s, TE = 21 ms/24 ms, GRAPPA = 3, pF = 6/8, $(0.8\,\text{mm})^3/(1.0\,\text{mm})^3$; Thin stripes: TR = 3 s, TE = 26 ms, GRAPPA = 4, pF = 7/8, $(1.0\,\text{mm})^3$.

Analysis

- SPM12 was used for GLM analysis (no spatial smoothing).
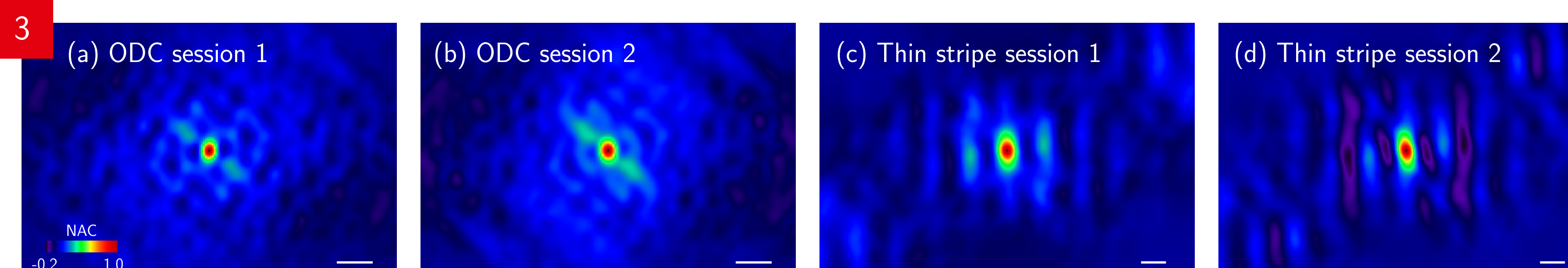- The cortex was segmented using FreeSurfer (cortical boundary surfaces were upsampled to 0.3 mm edge length).
- 10 surfaces at different cortical depths were created using the equi-volume approach. [3]
- V1 and V2 patches were manually defined and flattened.
- Flattened patches were interpolated onto a regular grid representation (isotropic 0.25 mm).
- Grids of single layers were stacked together to show functional contrasts across cortical depth.
- Normalized autocorrelation (NAC) maps were computed from the regular grid representation to visualize the repetitive columnar structure within the defined patches.
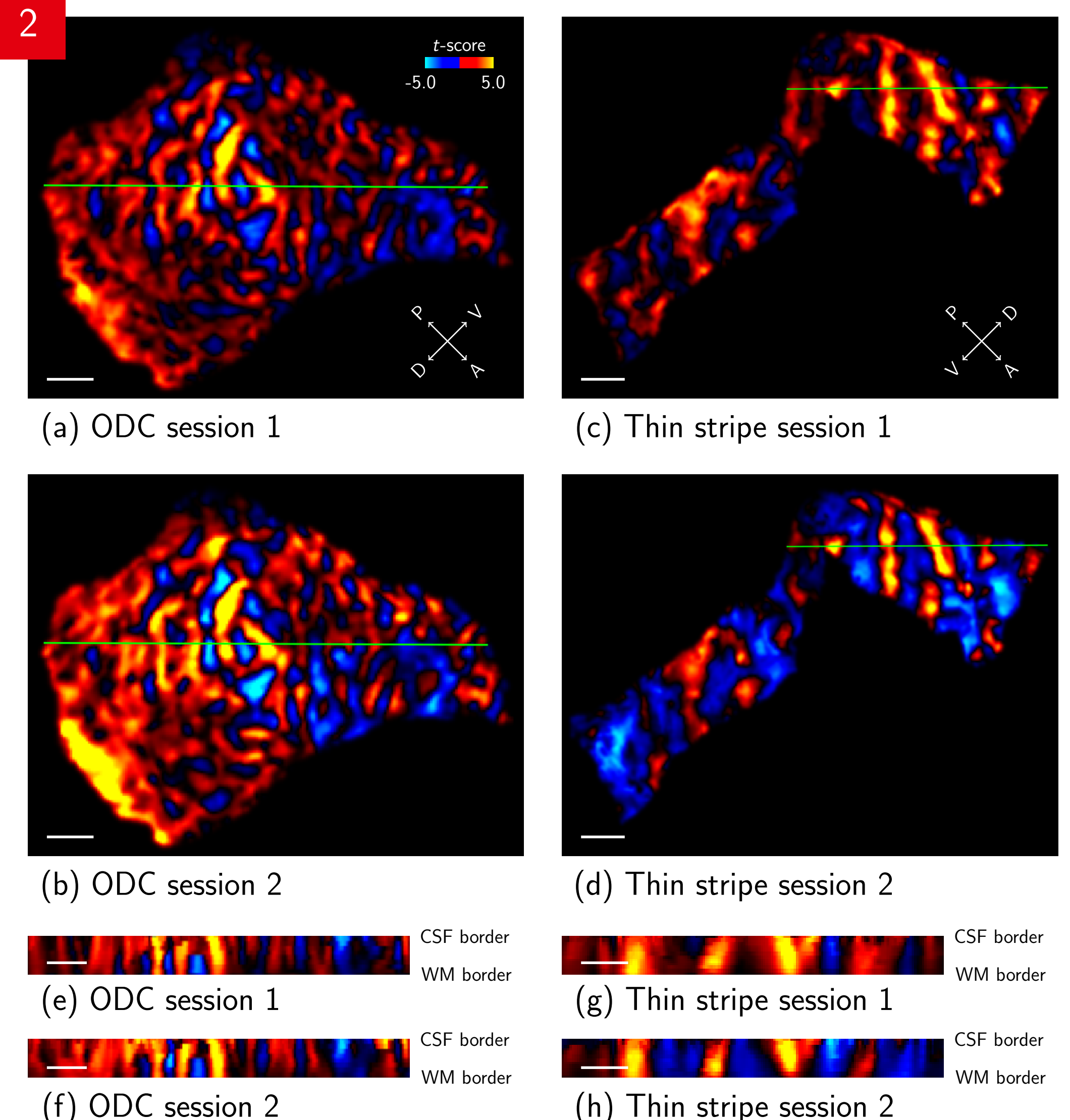
Results

(a) ODC session 1   (b) ODC session 2   (c) Thin stripe session 1   (d) Thin stripe session 2
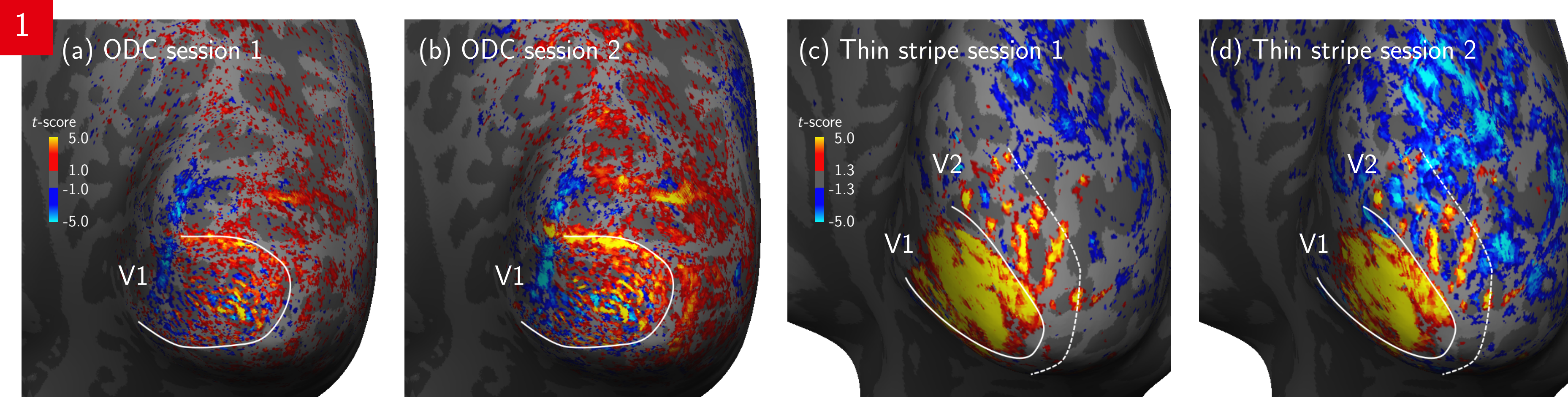
Activation maps Thresholded t-maps of ODC (a)–(b) sessions (left eye > right eye) and thin stripe (c)–(d) sessions (color > no color) sampled on the central cortical layer of the right hemisphere. (a) was measured with $(0.8\,\text{mm})^3$ voxel size whereas $(1.0\,\text{mm})^3$ was used in all other sessions. All sessions were aquired on different days. The expected shape of ODCs and thin stripes can be reliably identified.

(a) ODC session 1   (c) Thin stripe session 1
(b) ODC session 2   (d) Thin stripe session 2
(e) ODC session 1   (g) Thin stripe session 1
(f) ODC session 2   (h) Thin stripe session 2

Regular grid representation (a)–(d) show t-maps from the central cortical layer restricted to V1 and V2, respectively. (e)–(h) show these maps across cortical depth at height of the green line. The blurring towards the pial surface can be identified in all profiles. P: posterior, A: anterior, V: ventral, D: dorsal, white line: 5 mm.

(a) ODC session 1   (b) ODC session 2   (c) Thin stripe session 1   (d) Thin stripe session 2

Normalized autocorrelation (NAC) (a)–(d) show the autocorrelation maps from fig. 2(a)–(d). The periodic pattern reflects the repetitive columnar and stripe structure in V1 and V2, respectively. This qualitative presentation of columnar arrangement will be used in future work to quantify the change and spread of columnar representation across cortical depth. White line: 5 mm.

Discussion

- The study qualitatively demonstrates the feasibility of reliable ODC and color-selective thin stripe mapping across days using GE-EPI with isotropic 0.8 mm and 1.0 mm in line with [2].
- The regular grid representation of flattened cortical surfaces allows direct visualization of the hemodynamic blurring across cortical depth visible in all analyzed sessions.
- Future work will quantify the hemodynamic blurring across layers by examining periodicity and width of columnar structures in early visual cortex from autocorrelation maps.

References

[1] Polimeni J et al. *Neuroimage* 2010; 52:1334.
[2] Nasr S et al. *J Neurosci* 2016; 36:1841.
[3] Wagstyl K Surface Tools *Github repository* 2018.