Mapping colour-selective columns in V2 across cortical depth using GE- and SE-EPI

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Introduction

- At ultra-high magnetic fields ($\geq 7\,\mathrm{T}$), fMRI enables the delineation of mesoscale human functional structures.
- Recently, selective stripes were visualised in human visual areas V2-V3 based on colour and disparity selectivity [1] and differences in temporal frequency sensitivity [2], respectively.
- Although the spatial extent of those stripe-like structures may depend on cortical depth to some degree, they approximately follow a columnar arrangement penetrating uniformly the cortex [3].
- However, when using a gradient-echo (GE) echo-planar imaging (EPI) sequence, the activation pattern may suffer from the well-known bias due to draining veins, especially close to the pial surface [4].

Objectives

- Assessment whether spin-echo (SE) EPI, less influenced by spurious vasculature effects [5], improves the definition of colour-selective stripes across cortical depth in V2 compared to GE-EPI.
- Stripe width was determined to estimate signal specificity across cortical depth.

Methods

Experimental design

- One volunteer was invited to 5 scanning sessions at different days: 1 x MP2RAGE [6] plus standard retinotopy [7], 4 x colour-selective stripe measurement (2 x GE-EPI, 2 x SE-EPI), see fig. 1.

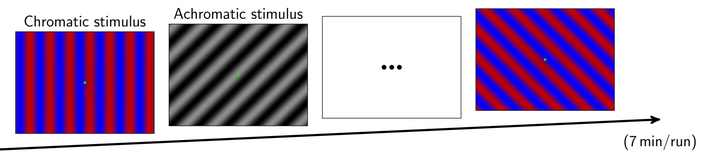
MRI data acquisition

- 7 T whole-body MR scanner (MAGNETOM 7T, Siemens Healthineers, Erlangen, Germany).
- 32 channel phased array head coil (NOVA Medical Inc., Wilmington MA, USA).
- For fMRI, 2D slices were acquired with $1\,\mathrm{mm}^3$ isotropic voxel size covering early visual areas.
- GE-EPI (TR = 3 s; TE = 26 ms; FA = 78°; GRAPPA = 4; number of slices = 56), SE-EPI (TR = 3 s; TE = 32 ms; GRAPPA = 4; number of slices = 42).

Analysis

- A multi-run fixed effects GLM was performed using SPM12 (contrast of interest: chromatic > achromatic).
- No smoothing was applied to the data.
- Cortex was segmented using SPM12 (for brain mask generation) and FreeSurfer with manual pial surface correction because of incomplete dura removal.
- For cortical depth-dependent analysis, the cortex was automatically contoured into four layers (deep layer, lower middle layer, upper middle layer, superficial layer) using the equivolume depth model [8] implemented in CBS tools.
- Contrast estimates were sampled from single layers and mapped onto the central surface mesh of the cortical surface reconstruction.

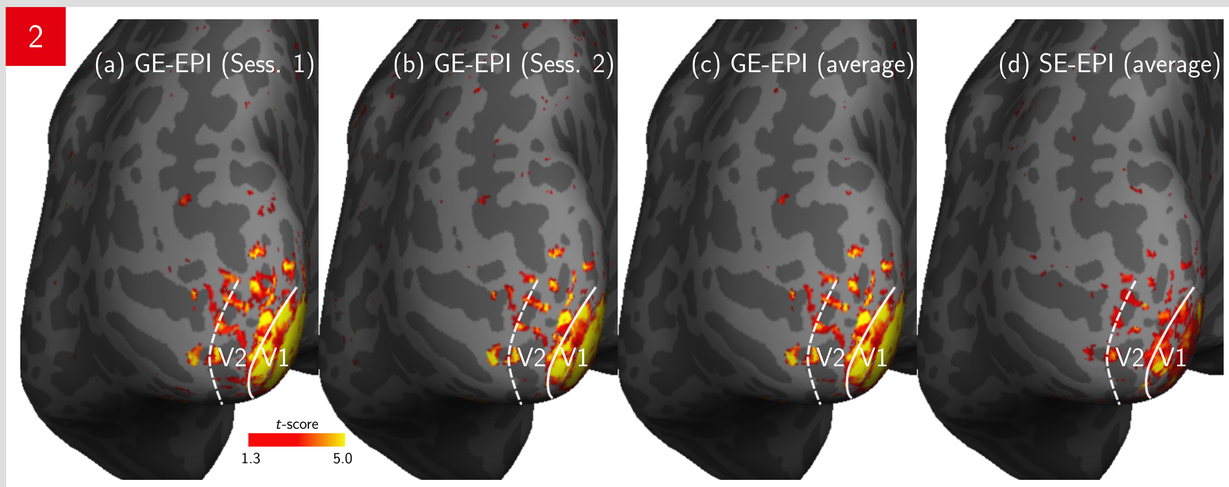
1



Experimental design Differential paradigm with 2 conditions (moving chromatic and achromatic gratings; 24 s/block). Details can be found in [1].

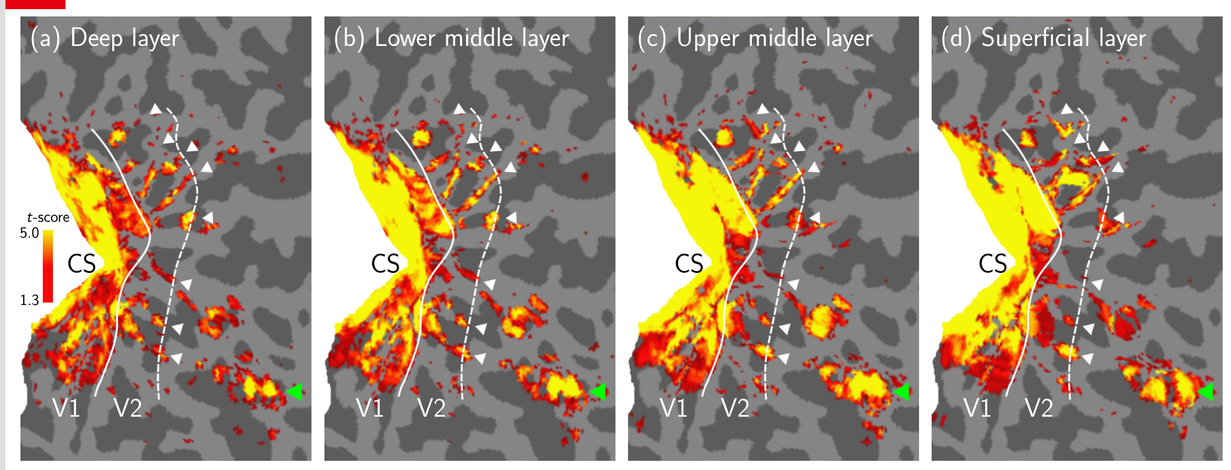
Results

2



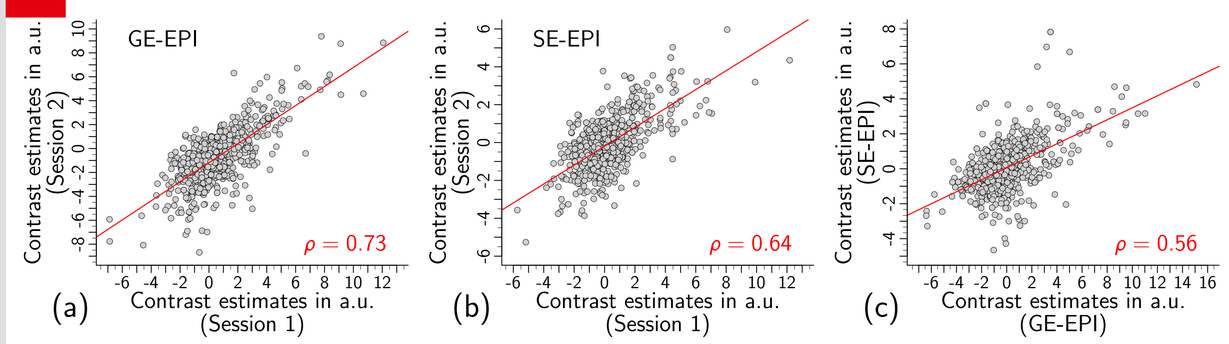
Colour selectivity Thresholded t-maps (no correction for multiple comparisons) on the inflated cortex of the left hemisphere. t-scores averaged across depth are depicted. (a)-(b) show estimates in single GE-EPI sessions, which demonstrates scan-rescan reliability. (c)-(d) show the average over GE- and SE-EPI sessions, respectively. The typical stripe-like structure can be identified in each map.

4



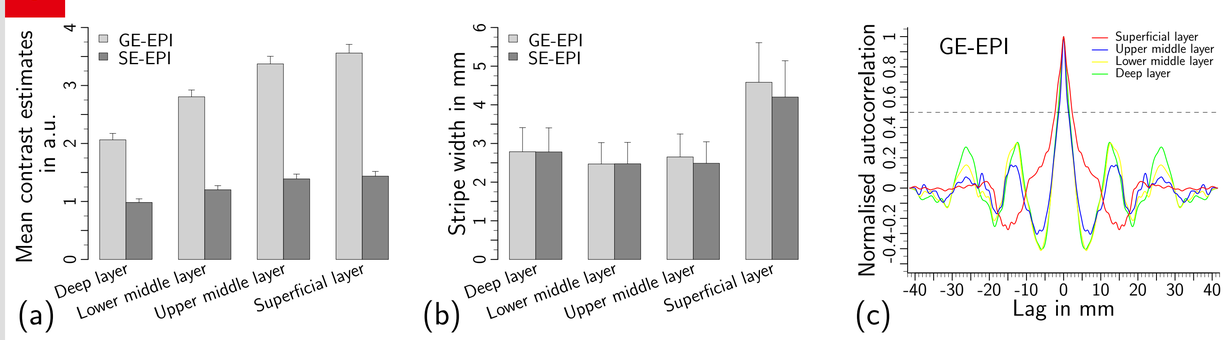
Colour selectivity across depth Thresholded t-maps (no correction for multiple comparisons) on the flattened patch cut through the calcarine sulcus (CS) of the right hemisphere. (a)-(d) show the average over GE-EPI sessions through cortical depth. White arrowheads point to putative colour-selective stripes in ventral and dorsal parts of V2. Green arrowhead indicates the colour-selective area VO/V8 [9,10].

3



Reliability measure Vertex-to-vertex correlations within V2 of both hemispheres. Estimates were taken from the deep layer. (a)-(b) show scan-rescan reliability and (c) illustrates reproducibility between sequences. Because of the spatial non-independence of neighbouring vertices, analysis was restricted to randomly selected 10% of vertices, cf. [1]. All correlations were statistically significant at the p = 0.0001 level.

5



Sensitivity and specificity (a) Mean contrast estimates within stripes in V2. (b) Mean width of colour-selective stripes in V2. First, contrast estimates were sampled from 10 lines parallel to the V1/V2 border on each hemisphere. Stripe width was then defined as the width of the normalised autocorrelation main peak at height indicated as dashed line in (c). Error bars mark standard error of the mean.

Discussion

- The study demonstrates the feasibility of mapping colour-selective columns at different cortical depths using GE- and SE-EPI.
- GE-EPI shows generally higher t-scores and a stronger dependence on cortical depth than SE-EPI.
- Stripe width estimations are similar between sequences with loss of reliability in the superficial layer indicated by wider stripe patterns in line with blurring due to draining veins.
- However, at deeper cortical layers, width estimations are comparable to [1].
- Overall, SE-EPI shows reduced sensitivity to the BOLD signal without improved specificity for measuring the topology of cortical columns throughout the cortex exemplified by colour-selective stripes in human V2.
- Future work will extent this study by increasing sample size and considering more sequences (3D GE-EPI, "inverse-keyhole" 3D GE-EPI and 3D-VASO [11]).

References

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