Distinct BOLD laminar profiles elicited by retino-cortical and inter-hemispheric sources in human early visual cortex

Alessio Fracasso[1], Natalia Petridou[2], and Serge O Dumoulin[1]

[1]*Experimental Psychology, Helmholtz Institute, Utrecht University, Utrecht, Netherlands,* [2]*Radiology, Imaging Division, UMC Utrecht, Utrecht, Netherlands*

Introduction: An ultimate goal of laminar imaging is to infer the origin of the signals by the functional laminar profile. High-resolution fMRI can derive activity profiles across cortical depth. However, profiles are contaminated with extra-vascular effects due to large draining veins, especially for gradient echo (GE) T2*-weighted fMRI. Here, we used sub-millimeter fMRI and a unilateral visual stimulation paradigm that elicits distinct responses in the two hemispheres driven by retino-cortical and inter-hemispheric sources (1). We compare the laminar profiles for these two conditions.

Methods: Four participants were scanned at 7T (Philips) using a using a volume transmit (Nova Medical) and a custom-built high-density 32channel surface coil (2). Anatomical T1-w images were acquired using a 3D MPRAGE adjusted to obtain a strong myelin contrast in gray matter (3) (TD=6s, TI=1.2s, TR/TE:8/3ms, flip:8^0, BW:202Hz/px, turbo factor: 275, 0.5mm isotropic resolution) which served as basis for laminar segmentation and cortical surface extraction. fMRI data were acquired using a segmented T2*w 3D EPI, TE/TR=27/54ms, SENSE factor: 3.5x1.5, resolution = 0.55 mm isotropic, 40 slices, FOV=144x144mm^2, volume TR=6.5s. Visual stimulation contrasted unilateral checkerboards versus mean-luminance (13s vs 26s). Participants fixated in the center of the screen. Checkerboard side changed on every run (6 – 12 runs per session). Laminar profiles were extracted sampling 1.25mm diameter cylinders along the surface of V1 and V2. Each cylinder was divided into 20 bins along laminar depth from the white/gray matter border. Time-courses were averaged for each bin, and the %BOLD signal change was computed to obtain the laminar response profile.

Results: Laminar BOLD profiles for the stimulated hemisphere increased linearly with increasing distance from the white/gray border, as previously reported (4). We isolated a predominant linear component by sorting profiles according to linear coefficient strength towards the pial surface (Fig 1a). Profiles showing a weak linear coefficient reveal a peak at the middle layers (Fig 1a,b). We interpret the two responses as profiles with different sensitivity to extra-vascular effects Absence of visual stimulation for the same hemisphere (i.e. stimulation of the other hemisphere) yielded an overall negative response for the same cortical locations with a decrease in the middle layers (Fig 1b). Similar results were obtained for V2 (Fig 1c).

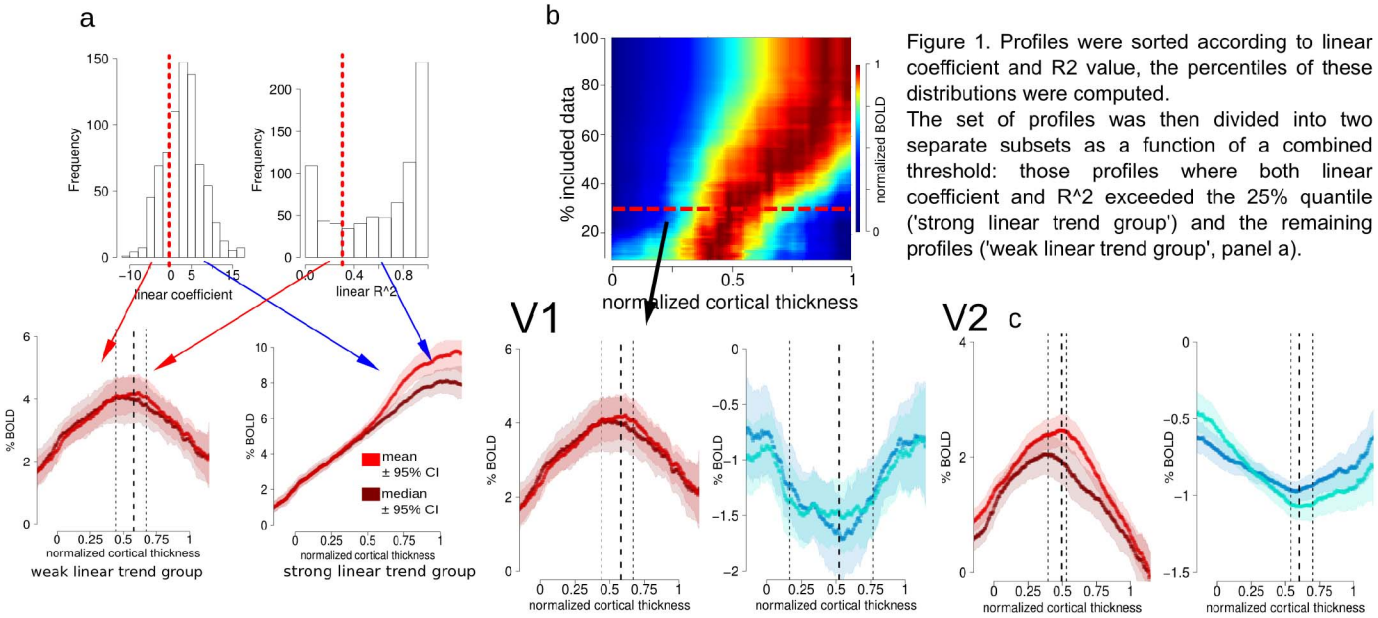

Figure 1. Profiles were sorted according to linear coefficient and R2 value, the percentiles of these distributions were computed. The set of profiles was then divided into two separate subsets as a function of a combined threshold: those profiles where both linear coefficient and R^2 exceeded the 25% quantile ('strong linear trend group') and the remaining profiles ('weak linear trend group', panel a).

To evaluate the effect of the combined threshold we derived the averaged profile for a set of quantile thresholds ranging from 10% of the dataset till 100% (the complete dataset). Inter-hemispheric profiles from the weak linear trend group show a mirrored negative profile (panel b). Similar profiles were obtained from area V2 (panel c).

Discussion: We dissociated two distinct BOLD profiles from contra-lateral visual stimulation. One profile reflects contributions of large draining veins to the GE signal, whereas the other reflects a more unbiased measure of signal strength reflecting retino-cortical input in granular layers. The latter, highlights the middle layers where geniculate afferents are known to arrive. BOLD profiles for the same cortical locations arising from stimulation of the other hemisphere were mirrored, showing a dip in middle layers, which may reflect suppression of activity in the granular layers (5). We speculate that these different profiles reflect different contributions of retino-cortical and inter-hemispheric afferent sources. This laminar specificity demonstrates that high resolution fMRI can be used to reveal the direction of information flow in the brain.

References: (1) Smith et al, HBM 21:213-220, 2004, (2)Petridou et al, NMR Biomed 2013, (3) Bock et al. J Neurosci Methods185:15–22, 2009, (4) Polimeni et al, Neuroimage, 52(4), 1334-1346, (5) Shmuel et al, Nat. Neurosci. **9**, 569-77, 20