# Laminar variation of population receptive field center-surround properties in human primary visual cortex revealed by 7T fMRI

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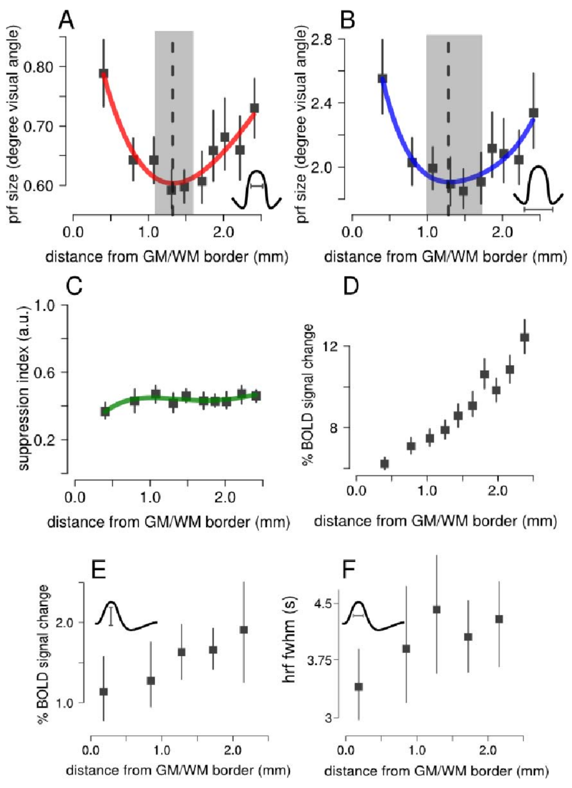
**Introduction:** Receptive field (RF) properties change systematically across visual hierarchy, in particular RFs enlarge at later stages of visual processing. A similar processing hierarchy exists across cortical lamina where information arrives at granular-layers and it is processed further in infra- and supra-granular layers. Invasive animal neurophysiology measurements suggest that input neurons have small visual receptive field (RF's) size, which presumably reflect their relative processing hierarchy, starting from granular-layers and spreading across cortical thickness (1,2). Here we use sub-millimeter resolution functional MRI at 7 Tesla and neuronal population receptive field (pRF) modeling to investigate the pRF properties in V1 across lamina, in humans.

**Methods:** fMRI data (3D EPI, 0.7mm, isotropic, TR/TE=57/28ms, SENSE=3.5X1.3 echo planar factor=27, flip angle = 20 deg., 35 coronal slices) were acquired at 7T (Philips, Netherlands) using two 16-channel receive arrays (MR Coils BV, Netherlands) and a volume coil from transmission (Nova Medical, USA). Participants (n=4) viewed an expanding and contracting contrast-defined ring centered on the fovea (4 deg radius). We estimated eccentricity, size and surround of the pRF for each voxel in V1, using a forward model (3). To avoid small realignment related errors, a Euclidean laminar distance map was based upon a gray matter(GM) / white matter (WM) manual segmentation derived from a weighted sum of the mean image of reconstructed fMRI amplitude and unwrapped phase (equivalent to anatomical T2*weighted images, 4,5). pRF size by eccentricity relation was estimated in 10 points across laminar distance. For each point, the corresponding pRF size was obtained. Haemodynamic response function (HRF) was estimated on the same participants with an independent scan (single-shot 2D EPI, 1.3mm isotropic, TR=0.850s, TE=27ms, SENSE=3.1 right-left, flip angle = 50 deg., 13 coronal slices), using an event-related paradigm design, as follows: uniformly permuted interstimulus intervals between 2.55s and 10.2s (mean 8.28s) in 1 TR steps, total of 44 stimuli, stimulus duration=850ms (two 425ms, full-field opposing checkerboard frames, size = 9 X 9 degrees of visual angle).

**Results:** pRF center and surround varies according to a U-shaped function across cortical thickness, indicating smaller center pRF size in the middle compared to superficial and deeper portions of primary visual cortex (Fig A, B). The ratio of pRF center and surround remains constant across cortical thickness (Fig C). Blood oxygen level dependent (BOLD) signal amplitudes increase monotonically towards the pial surface in line with the known vascular distribution (Fig D, 6). Independent estimates of the HRF show that pRF size laminar profiles cannot be explained by variations in the full-width half maximum (signal amplitude or FWHM) of the HRF (Fig E,F).




*Panel A: PRF center size estimates follow a U-shaped function, across cortical thickness. Panel B, the relationship of pRF surround size across cortical thickness. Panel C, suppression index as a function of distance from GM / WM border remains constant. Panel D: %BOLD signal change across cortical thickness, signal increases towards the pial surface; Panel E. %BOLD signal change estimated from an independent scan to estimate HRF properties towards pial surface. Panel F. HRF full-width half-max increases towards the pial surface.*

**Conclusions:** We reconstructed pRF size and surround across lamina in humans using sub-millimeter fMRI at ultra-high field, showing the characteristic U-shaped function predicted by invasive neurophysiology. These results show that careful experimental design allows to investigate aspects of laminar processing that are orthogonal to the more prominent influence of vasculature distribution across lamina. These results extend the systematic variation of pRF properties across eccentricity and visual field maps hierarchy to a laminar hierarchy within a visual field map.

**References** 1) Hubel and Wiesel, 1968, J Physiol. 195(1) 215-243; 2) Chapin, 1986 Exp. Brain. Res. 6(3) 549-559; 3) Dumoulin and Wandell, 2008, Neuroimage, 39(2), 647-660; 4) Duyn et al, 2007, Proc. Nat. Sci. USA, 104(28), 11796-11801; 5) Bilgic et al, 2014, J. Magn Res Imag, 40(1), 181-191; 6) Duvernoy et al, 1981, Brain. Res. Bull, 7, 519-579;