The cortical architecture presentation of visual system functional selectivity

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Introduction: A basic hypothesis in neuroscience is that function and structure are inter-connected. The human cerebral cortex has a well-known and defined cyto-architecture of organized six distinct layers, which was the basis for the brain parcellation into neuro-anatomical regions (1). Recent study (2,3), showed that inversion recovery (IR) MRI can be used to segment the cortex into layers *in vivo* and in 3D. Rodent studies were able to find correspondence between the IR MRI layers and the cyto- and myelo-architecture ones. This discovery yields the opportunity to explore, for the first time, the relation between layer architecture and brain function. The human visual system has a hierarchical spatial organization of different perceptual features. For example the visual cortex has several areas that are selective in function towards face, scenes or body stimulations (ref). In this study we set to explore the cortical architecture basis of the functional segregation of the visual system.

Methods and Analysis: MRI Experiments: Seven subjects underwent MRI in a 3T scanner (GE). The protocol included seven inversion recovery (IR) sequences with the following parameters: TR/TE=14000/8.4ms, matrix of 512x384 with final pixel size of 0.39x0.39 mm^2 and axial slices (1.5mm thickness) covering the entire occipito-temporal cortex. The inversion time (TI) varied for each experiment at the following values: 230, 432, 575 ,665, 760, 920, 1080, 1380ms. A block design fMRI experiment: An echo planar imaging sequence with TR=2s, TE=35ms, 24 axial slices with no gap covering the entire occipito-temporal cortex and resolution of 1.58x1.58x2.6mm^3. The Stimuli was comprised from three types of pictures (faces, bodies and scenes images). fMRI Analysis: Hemodynamic responses to faces, body and scenes were extracted using SPM5 with $p<0.001$. A manual selection of specific cluster was done to define the stimuli selective areas. We focused on 7 regions for each hemisphere - FFA, OFA and fSTS of face selective areas; EBA and FBA of bodies selective areas; TOS and PPA of scenes selective areas. IR-Analysis: The multi-dimensional IR images were analyzed using a multi-spectral clustering framework (5)(see Fig1) revealing 5 layers across the cortex. Gray Matter masking of SPGR was calculated by Freesurfer(6), which serve as mask for the clustering analysis. Normal extraction: SPGR was used for extract cortical surfaces using Freesurfer from the outer to inner pials. Overall 42 surfaces were generated, ensuring a complete coverage along the cortex. Cortical normals were generated from the outer to inner pials. Following co-registration of the SPGR, fMRI and IR datasets, for each fMRI cluster, we could extract the layer composition across the normals that were fully presented within the cluster.

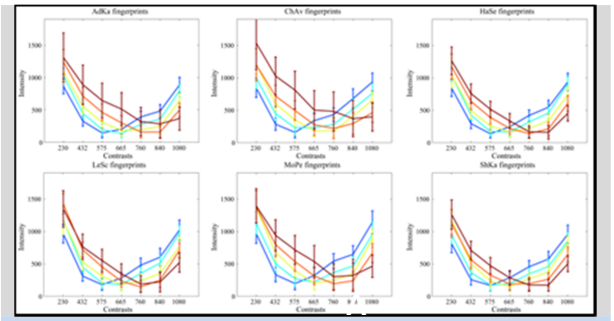

Fig. 1: IR profiles of the different cortical layers for 6 of the 7 subjects

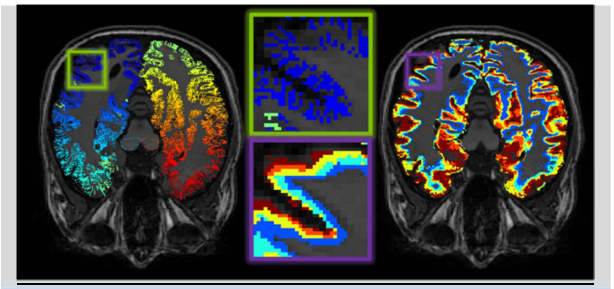

Fig. 2: Analysis pipline. (left) Cortical normal. (right) multi IR Layer clusters

Results and Discussion: Fig 1 shows the results of the k-means (k=5) clustering pattern between 6 of the 7 subjects. The clusters were consistent with similar characteristics between the different subjects. Fig. 2 shows the analysis pipeline: on the left - the cortical normals for one slice are presented while on the right - the layer clusters for the same slice (enlargement of a specific region is shown in the middle). Only normals that had full representation for both fMRI clusters and layer composition along the normal were further analyzed. Fig. 3 shows hierarchical clustering analysis (HCA, dendogram) for the cortical-normals data set. The dendogram was computed on the matrix of the 5 layers x 14 functional regions (7 for each hemisphere). The HCA revealed that the occipital visual regions (TOS and OFA) are different in their architecture than the others implying on distinct primary vs. secondary functional and anatomical presentation. In addition, the fusiform regions: the FBA (bodies) and FFA (faces) were separated to different dendorgram clusters indicating that even in the same cortical region, the functional differences between these regions is reflected in their anatomical features.

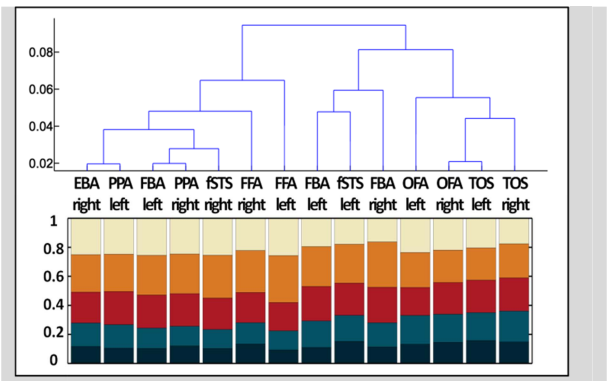

Fig. 3: (Top) Hierarchical clustering analysis of the mean cortical layer composition of all subjects (shown at the bottom) for each of the 14 regions (7 regions x 2 hemispheres)

Conclusion: The analysis pipeline described in this work shows how fMRI and cortical architecture measures can be combined. Using this approach we were able to investigate and reveal, for the first time, the anatomical basis of stimulation selectivity in the visual system. Our results indicate that different functional features of the visual cortex are also reflected in their anatomical architecture. **References:**(1).Brodmann K, Garey L. London River Edge, NJ: *Imperial College Press*. (2). Barazany D, Assaf Y. (2012): *Cereb Cortex* 2**2(9):2016-23.** (3). Barazany D, Assaf Y (2009): ISMRM annual meeting. (4) Kanwisher, N.G. (2010) PNAS, 107(25),11163-70. (5). Yovel Y, Assaf Y (2007): *Neuroimage* **35**(1):58-69. (6) Reuter, M., Schmansky, N.J., Rosas, H.D., Fischl, B. (2012).