IR-MRI layers of the visual cortex in Congenitally blind Subjects

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Purpose and Target:
The cortical layers are cytoarchitectonic features that consider as microstructural signatures of the brain that dictates its parcellation to neuroanatomical regions [1,2,3]. The ability to visualize the cortical layers in vivo with standard clinical MRI is complicated mainly due to limited resolution. Previous study showed [4] that using inversion recovery (IR), an enhanced image intensity along the cortex could be obtained which allow its segmentation into laminar clusters (IR-layers) in-vivo and in 3D, based on their T1 characteristics. Using this experiment setup, we set to explore changes of cortical lamination pattern due to brain impairment, such as in blindness, with the assumption that the lack of input to the visual cortex (V1 and V2 areas) in blindness will be reflected on the underlying cellular abundance and organization.

Methods:
MRI Experiments:
17 subjects split into congenitally blind (n=10) and sighted control (n=7) groups were recruited for this study, and underwent MRI at clinical 3T GE scanner. IR-MRI scans were acquired with different set of T1 weightings (by controlling the inversion time, TI) in the axial plane containing the primary and secondary visual cortices (V1 and V2 respectively). Additionally, 1mm isotropic anatomical SPGR scan was acquired.
Region Definition:
SPGR image was analyzed following Freesurfer [5] pipeline for defining neuroanatomical regions for each subject (including V1/V2 areas). In addition, we focus on the anterior/posterior parts of the motor cortex (Brodmann's area 4A and 4P), which were served as reference areas, where no differences are expected. Since the cyto-architectonic properties may vary due to lateralization, the left and right hemispheres were distinguished in the analysis (resulting with 8 areas overall; 4 areas X 2 hemispheres).
IR layers analysis:
Following head-movement corrections and co-registration of the multiple IR-MRI scans by SPM8 (London, UCL), the IR data was analyzed using a multi-spectral clustering framework [6] to segment the selected areas to 5 significant IR layers (K=5). The IR-layer composition of the selected areas is calculated for all subjects. Hierarchical cluster analysis (HCA) was applied to examine the relationship between the IR composition of congenitally blind and sighted control groups.

Results:
First, we were able to replicate the results of previous paper results [4], where the human cerebral cortex was subdividing into 5 laminar clusters (IR-layers). Fig.1 depicts the automatically defined visual and motor cortices and the measured IR-layers on a representative subject. The IR-layers intensity profiles were significant, but remain consistent among the blind and sighted groups (Fig.2). The IR layer consistency ensures that they represent similar tissue composition among groups. Then, the IR-layer assembly on each area was measure for each subject. An exemplar of IR-layer compositions on blind and sighted representative subjects are demonstrated in Fig.2. Note the differences between the two subjects, where sighted control subject has thick IR layer 4 and thin IR layer 3, while the opposite pattern obtained for the congenitally blind subject. Averaged IR-layer assembly was measured for subjects in each group, and further analyzed by HCA. The visual cortices HCA results are summarized in a dendrogram plot (Fig.3), which divides between the two groups. While the main differences within the sight subjects lays between V1 and V2 (and no lateralization), the blind subjects had lateralization, V1 and V2 of the same hemisphere has similar characteristics. No differences were found between the groups in the motor cortex.

Conclusions and Summary:
IR-MRI provides enhanced image profile that enables subdivision of the human cortex to laminar clusters. These clusters reflect microstructural organization in the cortex, which could be further used for visualizing and quantifying brain microstructural alterations due to brain impairment (e.g., blindness).

References:
[1] von Economo CB, Koskinas GN,1925 Julius Springer Verlag [2] Zilles and Amunts 2010, Nature Rev Neurosci [3] Brodmann 1909, Ambrosius Barth [4] Barazany et.al. 2012, Cerebral Cortex [5] Desikan, R.S. et.al. 2006, *Neuroimage* [6] Yovel, Y. et.al. 2007, *Neuroimage*

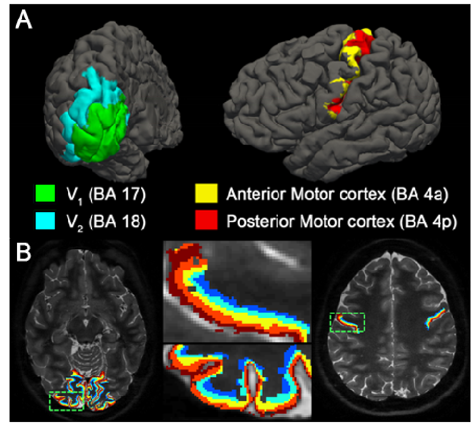

Figure 1: Measurement of IR-Layers of Visual and Motor Cortices
(A) The visual cortices (V1 and V2 respectively) and the motor cortex (BA 4A-4P) were defined based on SPGR scan. K-means Cluster analysis of multiple IR-MRI scans reveals five IR-layers along the cortex, characterized by a laminar shape (B). The IR-layers have distinct T1 properties.

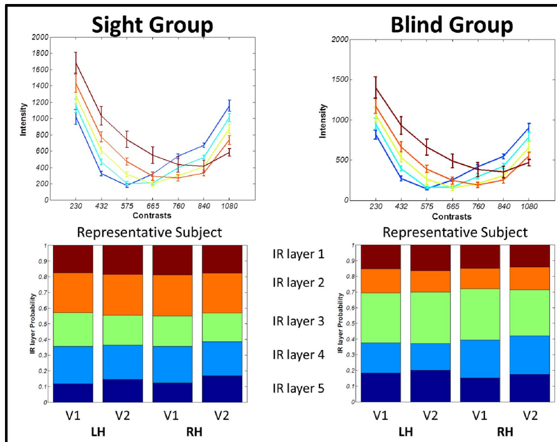

Figure 2: The IR-layers intensity profile of blind and sighted control groups
IR-MRI dataset undergo k-means cluster analysis to measure 5 IR-layers along the cortex. (Upper) Presentation of the subject-averaged IR-layer intensity profiles of the two groups. Note the consistency of the IR-layer profiles. The IR-layer assembly for each visual cortex is given below. The IR-layer assembly was further underwent hierarchical cluster analysis (see Figure 3).

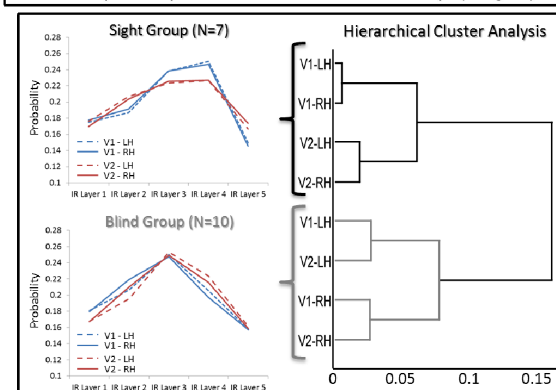

Figure 3: IR layers Composition of Visual Areas of Blind-Sight Groups
The IR-layers composition of the visual areas was examined by hierarchical cluster analysis (right). The dendogram shows that the blind and sight groups have distinct IR-layer composition in their visual areas. There were no differences between hemispheres in the sight group, but their V1 and V2 characteristics are different. At the blind group, the main differences found were between hemispheres.
(Left) shows the IR layer profile of each group for V1/V2 of left and right hemispheres.