Detection of orientation specific activation zones in human V1 using fMRI

E. Yacoub[1], K. Ugurbil[1], N. Harel[1]
[1]Center For Magnetic Resonance Research, University of Minnesota, Minneapolis, MN, United States

Introduction:

There have been several previous studies in humans and animals which have successfully used fMRI to map high resolution functional architecture in the brain at the level of cortical columns (1-2). Animal studies using fMRI have been able to map both orientation columns (3-4) as well as ocular dominance columns (ODC) (5) using several different contrasts. In humans, ocular dominance columns have been demonstrated using fMRI, however, attempts to *directly* map orientation columns have never been done. With the ability to do longitudinal studies in humans, fMRI maps can be robustly established and the reliability assessed. With this, apriori maps of ocular dominance columns, which we have previously demonstrated, can be used to predict an expected spatial organization of orientation columns. In this work, we demonstrate directly for the first time in humans, the existence of orientation specific activation using high resolution fMRI at high magnetic fields.

Background:

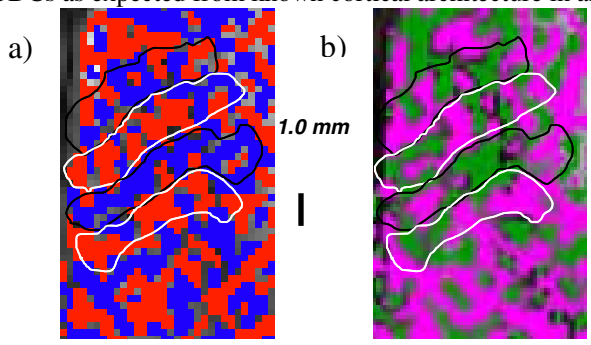
Neurons in visual area V1 are selective for the orientation of a bar presented within their receptive field. Neurons with preference for similar orientation are clustered together, forming columns that run orthogonal to the cortical surface. Using anatomical techniques (6) ocular dominance columns have been previously demonstrated in the human post-mortem brain. Histological staining for the enzyme cytochrome oxidase enhances regions that are metabolically active relative to resting regions. Such post-mortem histological studies in humans that lost one eye demonstrated stripes of active regions corresponding to their functional eye within visual area V1. In contrast, to date there has been *no* verification of the existence of orientation columns in humans, although based on the data from animal models they are believed to exist. Post-mortem studies are not capable of depicting the existence of these columns, as there is no obvious clinical syndrome that would make a specific group of these columns inactive. More specifically, unlike ocular dominance columns, orientation columns have no anatomical basis, and therefore can only be observed via functional properties of the neurons. Non-invasive mapping techniques with high degrees of spatial specificity, such as the techniques proposed in this study, present a unique opportunity to explore functional architecture of the human brain that before were unattainable.

Methods:

Studies were conducted at 7T using slab selective FOV reduction for HSE (TR/TE 6000/50 ms) with 3 image segments. The spatial resolution was: 0.5 x 0.5 x 3 mm^3 with minimal resolution loss due to EPI blurring along the phase encode direction. To minimize the effects of motion; subjects used a bite bar, image registration of small motion was used within and between scans, and scans with large amounts of motion and / or significant mis-registration problems, were discarded. The visual stimuli were presented through fiber optic video goggles (Avotec, inc.). Subjects initially participated in ocular dominance column studies and brought back for repeated studies to assess the reproducibility of the functional maps. Following successful differential mapping of ocular dominance columns, subjects were again brought back to attempt to map orientation specific regions using the same anatomical slice. Initial studies were conducted using a series of drifting bars alternating between 2 orientations (0 and 90 degrees) while presented binocularly. The activation maps were analyzed similarly to the ODC data. Functional maps from the different days and the different paradigms were registered to the same anatomical location.

Results:

The results from one subject are shown below. Figure 1a displays a differential ODC map (i.e. right eye minus left eye (red and blue) with a confidence of 85%. These maps of alternating ODC patterns have previously been demonstrated to be highly reproducible (7). In contrast, when the activation pattern for a drifting bar stimulus for 0 degrees is compared to 90 degrees (Fig. 1b; green and pink) an entirely different fMRI activation pattern appears. Clusters of pixels with similar orientation preference appear to run orthogonal to the ODCs as expected from known cortical architecture in animal models.



Conclusions:

We demonstrate here for the first time, the existence of cortical regions in human visual cortex which are orientation specific (i.e. 0 degrees vs. 90 degrees). In addition, we have registered these maps to ODC maps which show the anticipated spatial relationship between these sets of visual cortical columns. We are currently conducting studies to obtain multiple orientations using phase encoding techniques.

Fig.1 a) Results from single sessions of ODC studies (red & blue) and orientation studies (b) (green and pink) from the same subject. The ODC outlines are registered to the same locations on the orientation maps.

References: **1**. *Menon et al 1997* **2**. *Cheng et al 2001* **3**. *Kim et al 2004* **4**. *Duong et al 2001* **5**. *Harel et al 2002* **6**. *Horton et al 1990.* **7**. *Yacoub et al 2005*

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