Functional MRI of Somatosensory Cortical Reorganization in the Rat Brain

X. Yu[1], S. Wang[1], S. Dodd[1], D-Y. Chen[1], and A. Koretsky[1]

[1]National Institutue of Neurological Disorders and Stroke, National Institutes of Health, Bethesda, MD, United States

Introduction

There are few *in vivo* noninvasive methods to study neuroplasticity in animal brains. Functional MRI (fMRI) technologies, such as BOLD-fMRI, have been developed for animal brain mapping, but very few studies have used BOLD fMRI to study functional alteration due to plasticity in animal models. One major limitation is that fMRI maps are characterized by statistical parametric mapping with an arbitrary statistical threshold. This threshold is often varied in different subjects and in different cortical regions of the same subject [1, 2]. Here, we developed a method to analyze center of mass in cortical fMRI maps that is not sensitive to statistical threshold. The mass-centers of forepaw, hindpaw, whisker pad, and nose S1 regions were identified in the S1 with BOLD-fMRI. This approach was used to study sensory deprivation-induced cortical reorganization in the primary somatosensory cortex (S1). A large change in the nose representation was measured after whisker deprivation.

Methods

BOLD-fMRI was performed in rats anesthesized with α-chloralose. A total of fifteen male rats were imaged at 7-8 weeks of age. Nine of these rats had follicle ablation at postnatal 10 days and six control rats had a sham procedure at the same age. The detailed imaging setup is similar to that previously described [3]. Briefly, all images were acquired with an 11.7T/31cm horizontal bore magnet (Magnex, Abingdon, UK), interfaced to an AVANCE III console (Bruker, Billerica, MA) and equipped with a 9 cm gradient set. A 3D gradient-echo, EPI sequence was used for the fMRI studies. A single shot sequence with a 64 x 64 x 32 matrix was run with the following parameters: effective echo time (TE) 16ms, repetition time (TR) 1.5s, bandwidth 200kHz, filed of view 1.92 x 1.92 cm. This sequence gave isotropic resolution of 300 microns. A sub-skin electrical stimulation with 2.5 mA, 300μs pulses repeated at 3Hz was delivered to forepaw, hindpaw, whisker pads and nose in a block design stimulation paradigm (30s on/off for 3 times). The time series EPI data was analyzed with AFNI (NIH, Bethesda). Imaging processing was performed with customized Matlab and C scripts. Image display was performed using Amira (Visage imaging, CA) software.

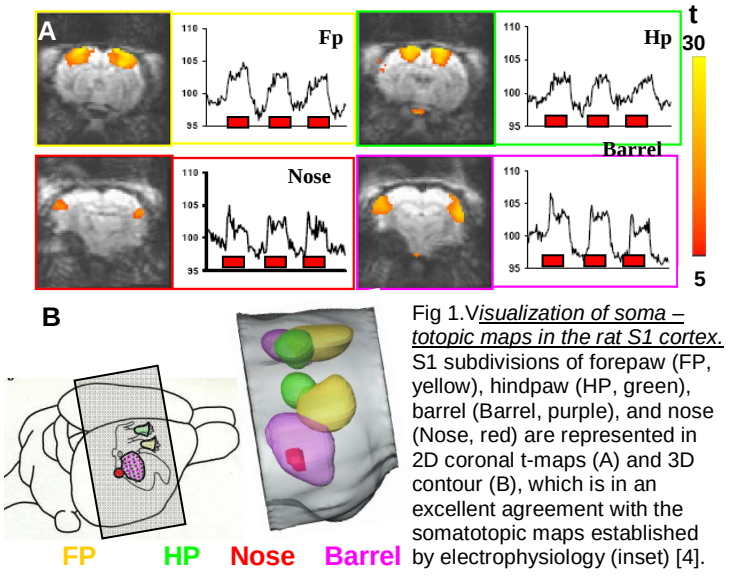

Fig 1.V*isualization of soma – totopic maps in the rat S1 cortex.* S1 subdivisions of forepaw (FP, yellow), hindpaw (HP, green), barrel (Barrel, purple), and nose (Nose, red) are represented in 2D coronal t-maps (A) and 3D contour (B), which is in an excellent agreement with the somatotopic maps established by electrophysiology (inset) [4].

Results

Four S1 subdivisions were characterized with BOLD-fMRI including the forepaw S1, hindpaw S1, nose S1 and barrel S1 cortex. In Fig. 1, a 2D t-map was superimposed on a coronal EPI image to represent the activity pattern for each activated S1 area. BOLD signal changes were analyzed along the time series at each S1 subdivision. The somatotopic map was visualized as color-coded 3D contours in the segmented semi-transparent rat brain, which is in excellent agreement with the functional maps established by electrophysiology (Fig. 1B). MRI functional maps varied largely according to the t-threshold used at the different S1 subdivisions, however; the location of the center of mass in S1 subdivisions was highly consistent regardless of the t statistics used. The variability of the location of the mass-center at different t-thresholds showed a less than one-voxel displacement for hindpaw S1 and nose S1 and a less than two-voxel shift for forepaw S1 and barrel cortex (data not shown). The mass-center distance between different S1 subdivisions was measured to determine if there was cortical reorganization in a well-established plasticity rat model with sensory deprivation in the barrel cortex at postnatal 10 days. A shorter mass-center distance between nose and hindpaw regions was observed in the rats with sensory deprivation of the barrel cortex-deprived rats (Fig. 2B).

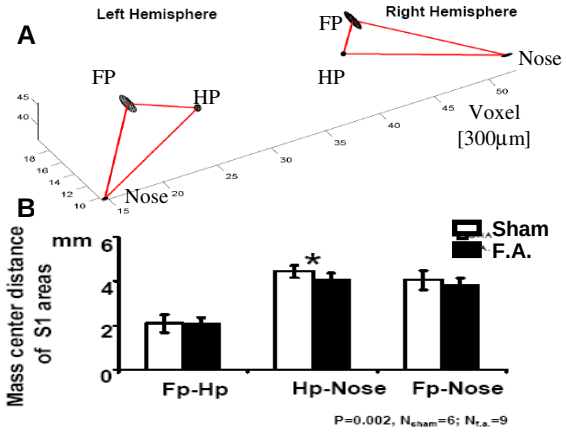

Fig. 2. Analysis of m*ass-center location in the S1 somatotopic map of rats with follicle ablation (F.A.).* In the 3D space, mass-centers of FP, HP and Nose in two hemispheres were represented as the three corners of a triangle (A). The ellipsoid superimposed at each corner indicated the variation of the mass-center location. Mass-center distances between three activated S1 areas in F.A. and Sham control rats were measured as Fp-Hp, Hp-Nose, and Fp-Nose. * means p<0.005 (B).

Conclusion

The mass-center may be a good functional landmark in 3D brain images to analyze cortical rearrangements due to brain plasticity. This study demonstrates a change in the nose cortical representation due to deprivation of the whisker cortex. Future work will extend this analysis so that quantitative analysis of the boundaries can be performed along with center of mass changes.

References [1] Huettel et al., Neuroimage **14**:967-76 2001. [2] Huettel et al., Neuroreport **8**:2411-6 2001 [3] Silva AC and Koretsky AP, PNAS, **99**: 15182-7. 2002 [4] Hickmott P et al. J. Neurophysiol. **88**:1288-1301. 2001.