Assessment of Functional Cortical Plasticity with BOLD fMRI Mapping of Adjacent Somatosensory Representations in Rat

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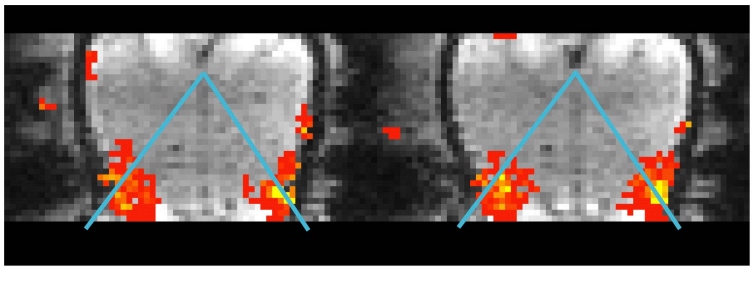
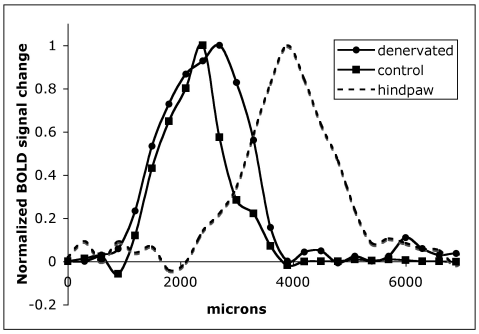
Introduction: A detailed assessment of the reorganizational capacity of adult brain is important for the investigations of the mechanisms of functional cortical plasticity [1]. In this work, a three-dimensional BOLD fMRI mapping of somatosensory limb representations [2] was used to study cortical reorganization/plasticity in adult rat brain, following peripheral nerve deafferentiation.

Materials and methods: Sprague-Dawley rats (100g, 5 weeks old, n=6) underwent an excision of the sciatic and saphenous nerves in a single hindpaw. fMRI measurements were conducted 2-3 weeks following the nerve deafferentiation. For fMRI experiments, the animals were secured in a stereotaxic holder inside the 11.7 T/31 cm magnet (Magnex Scientific, Ltd., Abington, UK) and anesthetized with continuous infusion of alpha-chloralose. A home-built receive-only surface coil was used. A gradient-echo 3D EPI sequence was employed with isotropic resolution of 300 microns (64x64x32 matrix). TE was 13.22 ms and TR was 1.5 s. Both forepaws were simultaneously stimulated by 0.333 ms rectangular pulses of 2.5 mA current at a repetition rate of 3 Hz. The stimulation paradigm of a single fMRI trial consisted of 5 epochs (200 scans). Each epoch employed 30 s of stimulation (20 scans), bordered by 15 s rest periods (10 scans). At least 13 trials were collected for each animal. Upon completion, images were separately averaged on a pixel-by-pixel basis. Then, t-maps of BOLD signal ($p < 0.05$) were calculated in units of percent signal intensity change. Profiles of BOLD signal were manually selected through regions of interest for subsequent analysis.

Results: Figure 1 shows averaged BOLD activation maps of bilateral forepaw representations overlaid upon EPI images in horizontal orientation (2 slices shown). The left hemisphere in the images corresponds to the denervated hindpaw. The data shown was obtained using one rat and is representative of all animals. Figure 2 shows the averaged and normalized BOLD signal profiles from the activation maps corresponding to the isosceles sides of the ROI (blue selection line in Figure 1) and thus demonstrates a comparison of the normal forepaw representation to the reorganized one.





As can be seen from the alteration in functional map profiles (Figure 2), an expansion of the forepaw representation into the cortical area corresponding to the hindpaw occurred. Since no structural/neuroarchitectural changes are associated with plasticity in the adult brain, the observed capacity for the functional plasticity can be attributed to unmasking of the existing connections, which are normally not expressed (e.g. alteration of local inhibitory interactions could produce this expansion).

Conclusions: The three-dimensional fMRI technique with a sufficient data averaging significantly improves the delineation of the functional maps and allows a detailed mapping of the induced plasticity of the cortical somatosensory representations when employed in rats.

References:

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[2] Goloshevsky, A.G. et al., 2007. Mapping of adjacent somatosensory representations with fMRI. OHBM 13th meeting proceedings, Chicago, IL.