Localized Active Shimming for fMRI Signal Recovery

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Introduction

Mapping the brain neuronal activity by fMRI using fast non-spin-echo pulse sequences usually has difficulty obtaining accurate data in the inferior frontal cortex (IFC), where the magnetic field is seriously distorted due to the geometrical shape and the change of the magnetic susceptibility across boundaries of the brain, the nasal cavity, and the sinuses (Ref. [1] and references therein). The field distortion results in MRI signal loss and image artifacts. Therefore, correcting the field distortion in the IFC is essential to obtain accurate fMRI activation maps. Previously [2], we showed that the magnetic field produced by the currents in circular coils held in the mouth can effectively shim the field in the brain, and the region of interest to shim as well as the shim currents can be adjusted for optimal results on a patient by patient basis. A recent work [3] on passive shimming using highly diamagnetic material held in the mouth also found that adjustable parameters are desirable. In this work, we further study the application of the mouth shim coil to the fMRI brain activation mapping.

Methods

Computational results [1, 4] suggest that, approximately, the *z*-component of the magnetic field in the frontal lobe has axial symmetry and is nearly matching a dipolar field. Therefore, the primary shimming field can be generated by currents in circular coils held in the mouth. In this work, the mouth shim coil set contained two concentric circular coils (diameter 1.6 cm, 80 turns and 2.2 cm, 50 turns). The coil set was secured by a sport mouth guard which attached to the subject's upper teeth; the center of the circular coils was ~4 cm deep from the front teeth. To determine the shim currents, a test current (60 mA) was input to one of the circular coils and a B_0 map was acquired; then the procedure was repeated for the other coil. The B_0 maps were subtracted by a third B_0 map obtained without any current so each subtracted map represents the shimming field generated by the test current. Then the required shim currents were solved by least-square fitting (using SVD) to eliminate the third B_0 map. The B_0 maps and the fMRI activation maps discussed below were obtained by the spiral pulse sequence [5]. The experiment was performed at 1.5 T.

Results and Discussion

Figure 1 shows axial B_0 maps of a healthy volunteer without and with the mouth shim currents. The boxed area is the region of interest in which the pixel values were used to calculate the shim currents. Notice the improvement in field homogeneity by the mouth shim. Figure 2 shows the activation maps by fMRI of the same volunteer performing a breath-holding and normal-breathing interleaved task. Considerable signal enhancement and recovery can easily be identified in particular in the frontal lobe. The areas of improved activation signal agree with those of improved magnetic field homogeneity in Fig.1, which implies that the present active mouth shim with adjustable currents is effective in fMRI and shows the potential in more specific applications.

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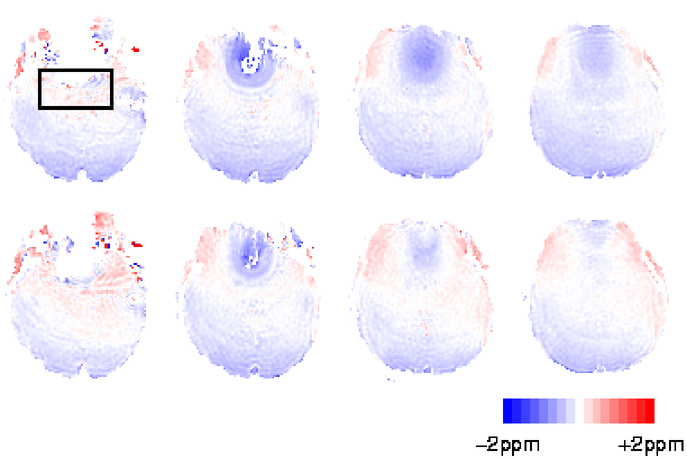

Figure 1 Axial brain B_0 maps without (upper row) and with (lower row) mouth shim currents (20 mA in the smaller coil and 32 mA in the larger one).

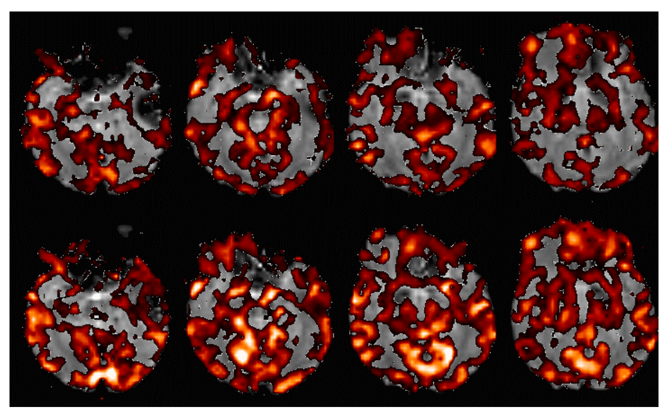

Figure 2 Comparison of activation maps in a breath-holding experiment by brain fMRI without (upper row) and with (lower row) mouth shim currents. T_E = 40 ms.