Effects of the TMS coil on MR image quality in combined TMS/fMRI

A. Bungert[1], and R. W. Bowtell[1]

[1]Physics and Astronomy, University of Nottingham, Nottingham, Nottinghamshire, United Kingdom

Introduction:

Transcranial Magnetic Stimulation (TMS) is a non-invasive method for directly stimulating cortical regions of the brain and when combined with fMRI forms a useful method for probing brain connectivity. Several studies have proven, that simultaneous application of TMS and MRI is possible (1,2). Some studies have also been carried out to analyze the problems occuring in the combination of TMS and MRI including general artifacts (3), TMS coil positioning (4) and synchronisation (5). In this study we analyze the effect of the TMS-coil on the B_0 and B_1 field homogeneity and explore its general influence on the image quality.

Methods:

The TMS-system used was a "Rapid[2]" stimulator from the Magstim company together with an MR-compatible figure-of-eight TMS-coil with a coil diameter of 70 mm. Data were acquired from a human subject and a spherical phantom on Philips Achieva MR systems operating at 1.5 and 3 T. The spherical phantom had an outside diameter of 18 cm and was filled with saline doped with Gd-DTPA resulting in a T_1 of 700ms at 3T.

A double surface RF coil of 20 cm diameter placed anterior and posterior to the head/phantom was used for this study, since it was not possible to accommodate the TMS coil inside the volume head coils available. The stimulator was positioned outside the scanner room and the coil was connected by leading its cable through a wave-guide into the screened room. Two different coil positions were studied: (i) superior to or (ii) on the left side of the head/phantom. In both cases the long axis of the figure of eight TMS-coil was horizontal. This covers two different orientations of the TMS-coil in the scanner, which are perpendicular or parallel to B_0.

Noise measurements were made by using an EPI sequence with 64x64x64 (phantom) or 64x64x40 (human) matrix, a voxel size of 3x3x3 mm^3 a TE of 35 ms and a TR of 4.2/2.8 s. 30 dynamics were acquired and the temporal standard deviation was measured for each voxel to characterise the noise level. Noise measurements were made: without the TMS-coil and with the TMS-coil in place, in the latter case with the coil connected to the TMS-stimulator or without the cable leading into the scanner room. A B_0 map was acquired from a double-echo 3D GE sequence (TE =2.2/20 ms) with the same resolution and B_1 was measured using a double-delayed, steady state sequence incorporating two RF-pulses per TR period (6). The slice orientation was trans-axial in all cases.

Results:

B_1-inhomogeneity: Figure 1 shows that the B_1 field is somewhat reduced close to the TMS-coil, but while at 1.5 T the strongest inhomogeneity is caused by the TMS-coil, at 3 T, the inhomogeneities induced by the head or phantom are stronger.

B_0-inhomogeneity: Figures 1 and 2 show that some B_0 inhomogeneity is produced by the TMS coil, but most of the coil's influence on the field can be eliminated by shimming. However some image distortion in the phase encoding direction of the EPI data, occurring close to the coil can be related to this effect, when scanning phantoms (Fig. 1). In a human head the skull introduces a space between the TMS-coil and the brain so that the additional B_0-artifacts are negligible compared to those caused by the field inhomogeneities related to the head itself.

Noise and SNR: The results shown in Figure 3 indicate that the presence of the coil causes a slight reduction of the overall image quality, which cannot be clearly related to B_0 or B_1 effects. When the cable of the TMS-coil was led outside the scanner room, influences of external RF could be observed in form of some noisy points in each slice. In the 1.5 T scanner, the overall noise level was increased by a factor up to 4 when the cable of the TMS-system was guided out of the scanner room (Table). This is a consequence of the cable picking up RF close to 64 MHz from outside of the scanner room.

Conclusion: Apart from a region close to the TMS-coil (< 1 cm distance), the influences of B_0 and the B_1 inhomogeneities due to the coil are so small, that no considerable influence on images should be expected. Nevertheless in most cases the TMS-coil causes a slight reduction in the global SNR. Problems occurred at 1.5 T, because of the pick up of external RF-noise, which decreased the overall SNR. This problem could be solved by filtering or shielding the TMS-lead or by putting the stimulator into the scanner room.

References: (1) Bohning *et al* Biological Psychiatry. **45**:385-394, 1999; (2) Bestmann *et al* J. Neurosci. **19**:1950-1962, 2004; (3) Baudewig *et al* Magn. Reson. Imag., 18:479-484 2000.; (4) Bohning *et al* Clin Neurophysiol 114:2210-2219, 2003; (5) Bestmann *et al* J. Magn. Reson. Imag., 114:309-316 2003; (6) Yarnykh, Magn. Reson. Med. 57:192-200, 2007.

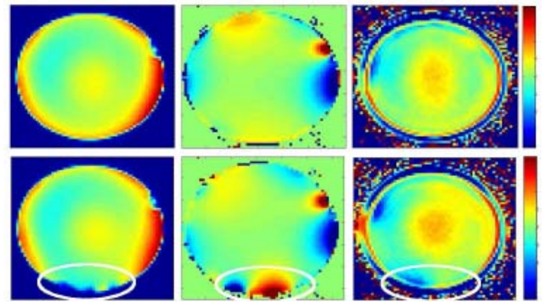

Figure 1: *A central slice of EPI data (left) , B_0-map (centre) and B_1-map (right) acquired at 3T from the same phantom without (top) and with (bottom) the TMS coil. The scale for the B_0 -map ranges from -200 Hz to 200 Hz and for the B_1-map from 60% to 110% of the desired flip angle. The effect of the TMS-coil can be seen on the bottom of the images which corresponds to the left side of the phantom.*

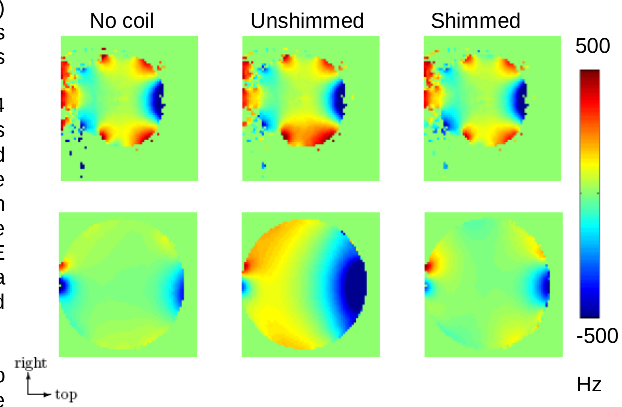

Figure 2: *Sagittal B_0-maps measured on a human head at 3T (top). The TMS-coil was positioned on the left side of the head. In this orientation, the diamagnetic copper increases the magnetic field in the brain region next to the coil. This effect can be eliminated nearly completely by shimming (right). Bottom: as in the top images but on a phantom and with the coil on the top. In this orientation the diamagnetic copper reduces the field in the adjacent brain region.*

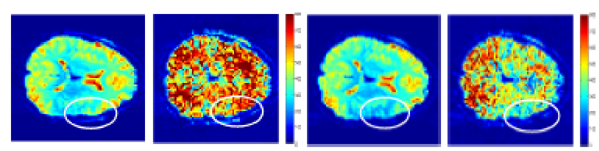

Figure 3: *Mean values and SNR-map acquired at 3T, without TMS-coil (left) and with TMS-coil (right). The ring highlights the region of influence of the TMS-coil.*

	3 T Phantom		3 T Head		1.5 T Phantom.	
	Left	Top	Left	Top	Left	Top
No coil	84.5	107.8	38.4	20.6	76.9	72.7
Coil con.	84.7	84.1	29.1	21.3	17.6	25.1
Coil unc.	76.4	80.4	28.6	18.5	76.1	76.0

Table: *(Mean/temporal standard deviation) averaged over a masked brain volume with different configurations (no TMS-coil; coil connected to the stimulator; coil unconnected and lead left in shielded room) and two different coil positions (left & top).*