

Evaluation of language processing in fMRI at 7 T

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Introduction: Functional magnetic resonance imaging (fMRI) has become a widely used approach for neuroscience in the last years. It is one of the most likely applications to benefit from high field MRI, as this method has the potential to be improved with increased spatial and temporal resolution and profit from the higher signal-to-noise ratio (SNR) and increased BOLD contrast itself (Vaughan et al., Magn Reson Med 2001 46: 24-30). The blood oxygenation level dependent (BOLD) contrast represents signal changes in T2 or T2* weighted images. The enhanced sensitivity to susceptibility of the requisite sequences, however, can also cause problems, e.g. in-plane dephasing and signal dropouts near tissue-air boundaries. However, since whole brain coverage with good temporal and spatial resolution has previously been shown to be possible at higher field strength (Gizewski et al, Neuroimage 2007 Sep 1;37(3):761-8), we used the aforementioned advantages to evaluate language regions with 7 T.

Methods: Twelve male, right-handed volunteers (mean age 28.1 years, range 20 to 33) were measured at both 1.5 T (Sonata, Siemens Healthcare, Erlangen, Germany) and 7 T (Magnetom 7 T, Siemens Healthcare, Erlangen, Germany) solving two tasks with fMRI in a block design fashion. First a "word generation" test, targeting primarily at the Broca's area and second a synonym detection test, aimed at the Wernicke's area were performed. At 1.5 T a 3D MPRAGE sequence (TR 1800 ms, TE 3.9 ms, TI 1000 ms, flip angle 10°, FOV 240x240 mm², matrix 256x256, 0.94 mm³) was acquired for individual co-registration of functional and structural images. BOLD contrast images were acquired using a gradient echo-planar technique (EPI) (TR 3100 ms, TE 40 ms, flip angle 90°, FOV 240x240 mm², matrix 64x64) with 36 slices with 3 mm thickness and 0.75 mm slice gap. At 7 T a 3D MPRAGE sequence (TR 3000 ms, TE 2.19 ms, TI 1100 ms, flip angle 6°, FOV 256x256 mm², matrix 256x256, 1.0 mm³ isotropic) and an EPI sequence (TR 3100 ms, TE 28 ms, flip angle 76°, FOV 256x256 mm², matrix 192x192 with 34 transverse slices with 2 mm thickness and 0.6 mm slice gap) were acquired as well. EPI resolution at 1.5 T: 3.75 x 3.75 x 3 mm³, at 7 T: 1.33 x 1.33 x 2 mm³ (both non-interpolated). An 8-channel transmit/receive head coil (Rapid Biomed, Germany) was used for image acquisition at 7 T and allowed parallel imaging (GRAPPA R = 3). Statistical analyses were performed using SPM 05 (Wellcome Department of Cognitive Neurology, London, UK).

Results and discussion: Cerebral areas involved in language processing, speech production, and comprehension (Broca's and Wernicke's area) could be consistently revealed using 7 T fMRI and with acceptable t-values. One volunteer revealed activation in both hemispheres, which was not detected at 1.5 T. The same corrected p value ($p = 0.001$) was used for all analyses. Furthermore, the BOLD signal change was significantly higher at 7 T than at 1.5 T. Bold contrast increase at 7 T was about a factor 2 (mean 9.4 with a range from 5.3 - 18 at 7 T and mean 4.9 with a range from 3.6 - 8.7 at 1.5 T). At the same time the acquired voxel level at 7 T was 5 to 6 times higher compared to 1.5 T (7 T: mean 1596, range 151-7543 and 1.5 T: mean 297, range 8-3088). A well-fitted response curve could be detected in all speech areas at 7 T. There were no major artifacts having an impact on the results.

Conclusion: We detected speech areas as Wernicke's and Broca's area reliably using whole-brain fMRI at 7 T with good quality response functions and, as expected, higher BOLD signal compared to 1.5 T, even while using higher spatial resolution. For further patient studies, the increased signal at 7 T may lead to consistent detection of speech areas, even if the examined group's ability for concentration is limited.

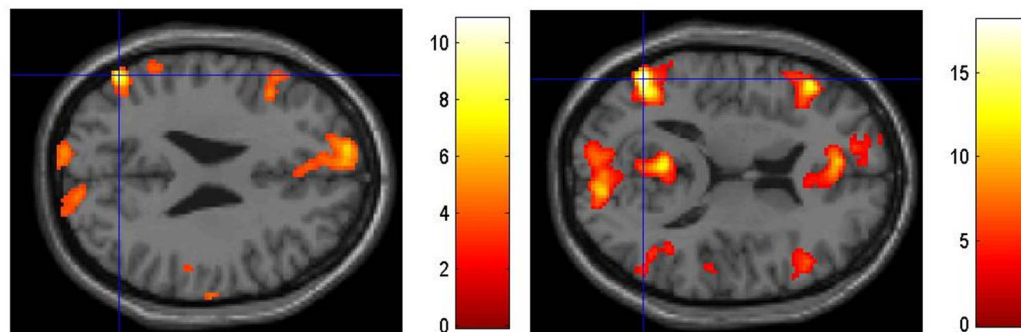


Fig. 1: Left: activation at 1.5 T, right: activation at 7 T (both Wernicke's area). Please note the different colorbar scales.

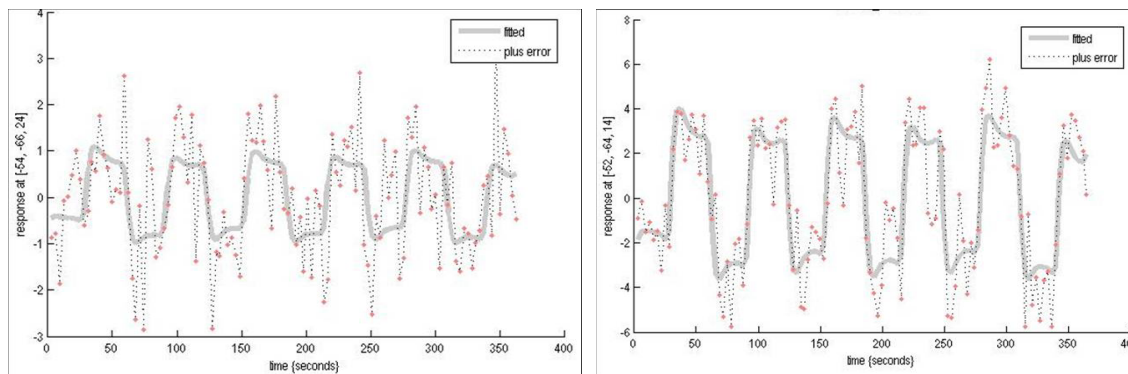


Fig. 2: Left: hemodynamic response curve (HRF) at 1.5 T, right: HRF at 7 T (both Wernicke's area). Please note the different scales of the y-axes.