

Increased Statistical Power of in Event-Related Real-Time fMRI (erfMRI) using Individual Hemodynamic Response Functions: First results at 3T and 7T

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Introduction Often for analytical techniques in fMRI and real-time fMRI assumptions about the hemodynamic response function (HRF) are used as basis. However, the variability of the HRF between subjects, and intra-subject between different brain regions [1] may reduce the statistical power when using a standard HRF estimate. This effect will be more pronounced in event-related fMRI. Acquiring more data to counteract this effect is generally not feasible in real-time fMRI [2]. Therefore, we analyzed the functional data in event-related real-time fMRI (erfMRI) with individual region-based HRF estimates that were acquired during the experiment-session prior to the main measurement. Using individual HRF estimates instead of the SPM canonical HRF led to an improvement in the statistical significance of a correlation analysis by an average of 25%.

Methods For erfMRI a GE EPI-BOLD sequence was modified to save the functional images after the reconstruction. Scanner control, presentation of the paradigms, and data analysis were controlled by an XML-based unified Experiment Description Language ("EDL") [3]. A custom-made MATLAB-based application analyzed the data in real-time on an external PC, and displayed the results to the experiment supervisor and the volunteer. Four healthy right-handed volunteers (m, 24–29 years) participated after written consent according to the local ethics committee. Experiments were conducted at a 7T and a 3T whole body MRI scanner (both Siemens, Erlangen, Germany). Measurement parameters were: TR 650ms, TE 21ms (7T) resp. 27ms (3T), resolution 64x64x10 (3T) resp. 64x64x6 (7T), flip-angle 55° (3T) resp. 60° (7T). Each experiment consisted of two measurements: the first part served to determine the individual HRF in the visual and motor cortices (MC) by applying an event-related paradigm with a long inter-stimulus interval. The paradigm consisted of 20 trials starting with a 1.3 sec baseline, followed by a 650 msec visual stimulus (8 Hz checker-board) and a second rest condition of a variable length (mean of 19.5 sec, SD: 2.6 sec). As soon as the volunteers perceived the visual stimulus they had to perform a single tap of the fingers of the left/right hand respectively. The signal was analyzed in real-time with a growing window correlation analysis using a boxcar function leading to activated regions of interests (ROI). The HRF-estimation was started automatically after selecting the activated regions in three orthogonal maximum intensity projections: a double-gamma function was fitted to the averaged signal time-course using a constrained simplex algorithm (computation time per region lower than 1 sec). The resulting HRF-map was then saved as an HRF template. In the following main experiments, this template was used to analyze the incoming data in real time in a single-trial correlation analysis with a constant sliding window. In a post-processing step the statistical significance values of the correlation analysis were compared to results achieved using the SPM canonical HRF.

Results and Discussion: Fig.1 shows the fitted individual HRFs for the right MC at 3T and 7T. The t-values performing the correlation analysis with the individual HRFs increased by +16.05% (Subject 1), +21.17% (Subject 2), +65.43% (Subject 3), and +15.34% (Subject 4). These results confirm that using individual HRF in event-related real-time leads to a strongly increased statistical significance especially if the HRF differs severely from the standard SPM HRF (cp. Subject 3). Although the mean

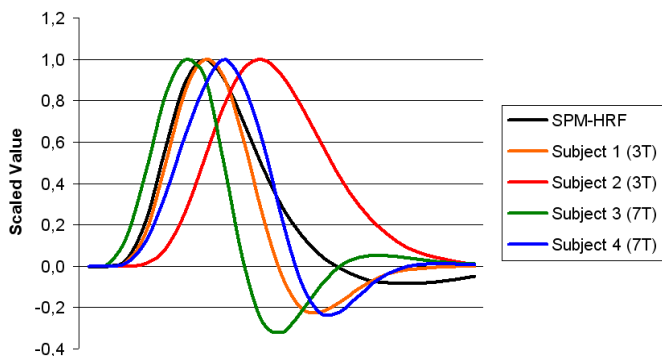


Fig.1 Fitted time courses of right MC compared to SPM canonical HRF at 3T and 7T.

signal percent changes were significantly higher at 7T the overall improvement using individual HRF's was similar with 26.4% at 3T and 24.1% at 7T. At the cost of only 7 min (to determine the individual HRFs) a significant gain in statistical power was achieved. The HRF estimation may be integrated into the determination of activated brain areas as templates that is commonly necessary in real-time fMRI. This integration would also provide the important information about the spatial distribution of the subject's HRF without additional time consuming experiments. For future experiments the HRF estimation may be realized using different stimulus designs and deconvolution techniques which may shorten the pre-measurements.

References: [1] D.A. Handwerker et al., *NeuroImage*(21), 1639–51, 2004. [2] N. Weiskopf et al. *Journal of Physiology* (98), 357–73, 2004. [3] Hollmann et al., *Proceedings of ESMRMB*, 2006.