First results of real-time fMRI at 3T and 7 T

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Introduction

Real-time functional MRI (rfMRI) offers new and interesting possibilities to examine functions of the human brain such as self-regulation of brain-activity, neuronal feedback, or optimising learning strategies [1,2]. However, some real-time paradigms may require short stimulus durations down to event-related stimuli which may impose problems on standard 1.5T or even 3T scanners. Additionally, real-time statistical analysis does usually not offer the full statistical strength provided by a General Linear Model. Increasing the field strength and consecutively the BOLD signal may counteract this effect, and allow a reliable detection of activated areas even with fast and less sophisticated statistical tests. We present first results of comparing rfMRI measurements at 3T and 7T with decreasing stimulus length. In a new approach, a unified system to control the experimental parameters, the stimulus presentation, and the statistical analysis is applied.

Methods

A standard EPI-BOLD sequence was modified to allow online saving of the functional images as the prerequisite of real-time analysis. Data were transferred online on an external PC and processed further. Experiment and data analysis were controlled based on a custom-made parameter/experiment description language ("EDL", based on XML). A MATLAB-based application was developed that reads the image data, performs spatial filtering and statistical algorithms for data evaluation, and visualizes the results. For the statistical analysis a t-Test as well as a correlation-analysis with a double-gamma function (approximating the hemodynamic response) were used. Results are displayed to the investigator and to the volunteer. Real-time fMRI experiments were conducted at 3T and 7T scanners (both Siemens, Erlangen) with a 64x64 matrix, TR=2s, TE=29s (3T) or 20s(7T), 31 slices (3T) or 16 slices (7T), resolution of 3.4 x 3.4 x 3mm^3 (3T) or 3.3 x 3.3 x 4.6mm^3 (7T). Three male subjects were examined at 3 T, one female and two male subjects at 7T (23 to 26 years) after giving written consent. The study was approved by the local ethics committee. Two paradigms (visual stimulation with 8-10 Hz checkerboard, motor paradigm with fingertapping) were measured. Activation/rest blocks of 20sec/20sec duration served to localize the activated areas unambiguously. Subsequently, stimulus duration was shortened from 10 sec over 4 sec, 2 sec to 1 sec to determine the minimum detectable activation. Each run consisted of a 26 sec window with defined stimulus duration. To determine the minimum detectable activation the stimulus duration was decreased from 10 sec, to 4 sec, 2 sec down to 1 sec. For the visual paradigm additional stimuli with a duration of 0.5 sec and 0.1 sec were applied. In the *constant window* mode each single run of 26 sec served for the statistical analysis. To increase the statistical significance the window was increased by each subsequent run thereby evaluating a growing number of stimuli (*growing window* mode).

Results

In the *constant window* mode visual areas were detectable at a minimum stimulus duration of 500 ms at 7T and 1 sec at 3T. Motor areas were reliably detected at a minimum stimulus duration of 1 sec at 7T and 2 sec at 3T. In the *growing window* mode visual areas were detectable at a minimum stimulus duration of 500 ms at 7T and 500 ms at 3T. Motor areas were reliably detected at a minimum stimulus duration of 1 sec at 7T and 1 sec at 3T. Mean signal percent changes were 2-3% (1s stimulus duration) for activated motor areas at 3T, and 5-6% at 7T. For visual areas we received mean signal percent changes of 3-4% at 7T and 2-3% at 3T (500ms stimulus duration). A clear activation of the primary auditory cortex was also seen which could be explained by the initiation of the motor activation by auditory stimuli ("start", "stop"). In those areas we detected a mean signal change of about 3%. *Figure 1* shows an example of a combined motor and auditory activation.

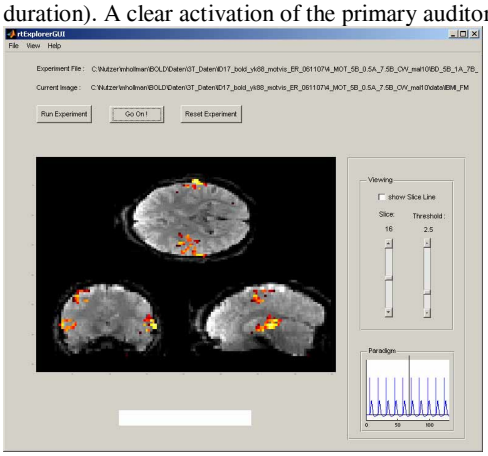

Figure 1 - Extracted activation-patterns in a growing-window experiment (1 second Finger tapping, right hand).

Conclusion

The results represent a first successful application of a new real-time imaging concept. Activated visual and motor regions could be reliably detected at 3T and 7T with stimulus duration as short as 1 sec. Motor activation below 1 sec could not be reliably verified, but at 7T visual stimulation with duration of even 500 ms was detectable. The results confirm that block as well as event-related designs should be feasible in real-time. At 7T the activated clusters were more homogeneous and the mean signal change was larger. This should enable the detection of smaller activated clusters and the analysis of more complex paradigms with several conditions. As a first result the simultaneous detection of the event-related auditory signal together with the motor reaction confirms this suggestion.

References

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