Whole-brain, sub-second data collection for task-evoked fMRI studies using simultaneous multi-slice/multiband acquisition

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Target Audience: Researchers considering using simultaneous multi-slice methods for increased temporal resolution in task-based BOLD studies.

Purpose: Slice-accelerated EPI using multiband (MB) RF pulses that allow for simultaneous multi-slice (SMS) acquisition of BOLD contrast images[1,2] can significantly enhance the temporal and spatial resolution of fMRI by acquiring as many as 8-16 non-contiguous slices at the same. This advance enables whole-brain fMRI at sub-second volume-TRs[3,4]. This is advantageous to resting-state fMRI, where faster sampling is beneficial to encoding sub-second frequency fluctuations[5,6]. However, the application of SMS to task-based fMRI, where longer volume-TR times have conventionally been used for purposes of stimulus presentation as well as due to MRI scanner hardware limitations, has not been investigated in as much detail[7]. Here, we studied visual cortex response at a variety of MB (SMS) accelerations and TR reductions to investigate the advantages and potential costs for task-based fMRI associated with parameters that allowed for whole-brain, sub-second data collection at 3 mm and 2 mm nominal isotropic resolution with both block and event-related design paradigms.

Methods: All measurements were performed using a 3.0 T MRI scanner (MAGNETOM Tim Trio, Siemens Healthcare, Erlangen, Germany), using the vendor-supplied 32-channel head coil. All subjects gave written informed consent according to a protocol approved by the local IRB. Slice-accelerated BOLD images were acquired using the Siemens WIP 770A sequence. For the block-design, six subjects were scanned while performing a fixation task as flashing checkerboards were presented to alternating visual fields. BOLD scans were acquired at 3 mm and 2 mm isotropic resolutions, a max TR of 3 s, and MB accelerations of 0 (conventional BOLD sequence), 1, 4 and 8. With a TR of 3 s, there were 91 time-points, while for TR = 1.25/0.75/0.7s at higher MB factors, there were 184/307/328 time-points, respectively. The event-related study was performed with similar parameters, but using only 2 mm voxels and TR = 3 s/MB1 or TR = 750 ms/MB8. Six different subjects were presented a flashing checkerboard to their upper left or lower right visual field for 250 ms with an ITI of 2, 4 or 6 s, with the stimulus jittered with respect to the TR. Betas and t-statistics (tstats) were extracted from regions localized in visual cortex using AFNI after standard pre-processing. Slice-time correction was performed for all event-related scans, but omitted for all block-design scans. For both experiments, tstats were corrected with an autoregressive moving average model (ARMA 1,1) in AFNI using a restricted maximum likelihood method, to account for temporal auto-correlations in the time series noise.

Results: In the block-design experiment, the higher temporal rate of sampling with MB4 or MB8 acceleration provided a much smoother and clearly resolved depiction of the hemodynamic response from ROIs on the visual cortex. tSNR was generally unaffected, either at constant or minimum TR, except for the MB8 acceleration at 2 mm resolution. Slice leakage was investigated by looking for significant false activations in unactivated quadrants – no significant leakage was found, as expected as the SMS sequence employed an advanced LeakBlock algorithm in its reconstruction[9]. tstats were observed to increase dramatically at the reduced TR's available with high levels of slice acceleration – see Fig. 1. However, after correction with the ARMA, tstats remained significantly higher than in the unaccelerated case ($F = 53.45$, $p < 0.01$). In the event-related study, data was analyzed from the full 30 stimulus repetitions observed by the subjects, or reduced sets of 20, 15, 10 and 5 repetitions. Here, the tstats were slightly higher with the short-TR scan for smaller subsets of stimulus repetitions, but this effect was lost over the course of the full experiment – see Fig. 2. After ARMA correction, this effect was lost and tstats were significantly higher for the unaccelerated case ($F = 25.92$, $p < 0.01$). However, betas were larger in short-TR scans, despite the stimulus onset being jittered to the TR period. The ARMA correction enhanced this effect ($F = 15.58$, $p < 0.05$).

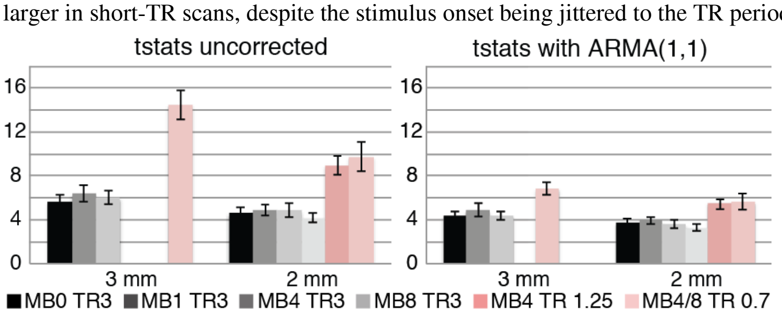

Fig. 1: tstats from visual cortex for the block-design experiment. Gray bars indicate scans using a constant (3 sec) TR, pink indicates minimum TR.

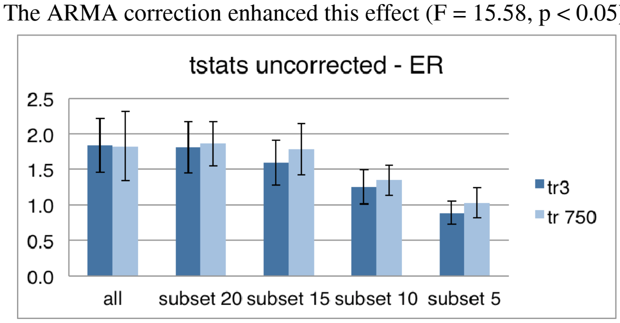

Fig. 2: Uncorrected tstats from visual cortex for the event-related design experiment, for both unaccelerated and MB8 scans.

Discussion/Conclusion: The observation of higher tstats in the short-TR scans is not surprising, simply due to the much larger number of time-points acquired[7]. However, the fact that a significant increase is still observed after ARMA correction indicates benefits to block-design experiments from high spatial and temporal resolutions with SMS sequences, even though tSNR decreases at high MB factors. To further investigate this result, the effects of higher-order AMRA models will be studied in future work, along with higher temporal resolutions. The observation of higher betas in the event-related design experiment with the short-TR scans is unexpected, and perhaps indicates the hemodynamic response is captured more accurately with the higher temporal resolution, despite the stimulus onset being jittered to the TR.

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