

Using wholebrain, high temporal resolution, 3D-EPI-CAIPI to observe multisensory interaction in primary sensory cortices

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Target audience: neuroscientists or physicists with an interest in high temporal resolution fMRI

Purpose: Most processes in the human brain happen on a timescale difficult to access with traditional fMRI acquisition methods. Recently, significantly accelerated acquisition methods have enabled the sampling of wholebrain fMRI data with subsecond temporal resolution and acceptable spatial resolution^{1,2}. In this study, we used 3D-EPI-CAIPI³ with 400ms temporal resolution and 2mm nominal spatial resolution to investigate its ability to detect previously demonstrated⁴ multisensory facilitation in the primary visual and auditory cortices.

Methods: Three volunteers were scanned at 7T (Siemens, Germany) with a 32-channel rf-coil (Nova Medical, USA). The stimulus protocol was based on that of⁴: volunteers were asked to report via a button-press the occurrence of either a visual flash (V, 150 ms, yellow/black checkerboard), a sound presentation (A, 150ms, white noise burst delivered via Sensimetrics earplugs) or a combination thereof (AV). Per 8-minute run, 30 stimuli were presented using E-prime, which also recorded response times. Stimuli were presented every 15-17s, lagging the volume trigger by either $\frac{1}{2}$ TR or 0s.

Data acquisition was done using a standard 2D-EPI sequence with TR=2000s and a 3D-EPI-CAIPI² acquisition with volume TR=400ms. Shared parameters: FOV 210*174mm, nominal spatial resolution 2*2*2mm³, TE=26ms, BW=2774Hz/Px, slices AC-PC aligned with the phase-encoding direction RL, no GRAPPA acceleration in phase-encoding direction. Two runs were acquired for each acquisition type. For the 2D-EPI: TR_{volume} = 2000ms, 40 slices/volume and for 3D-EPI-CAIPI: TR=57ms, TR_{volume}=400ms, 60 slices/volume, GRAPPA_{zdir} = 6, CAIPI- Δ = 2, Partial Fourier, PF_{zdir}=6/8.

SPM8 was used for motion correction, smoothing (FWHM 3mm) and the GLM analysis with regressors for A, V and AV stimuli and the temporal derivatives thereof. ROIs of ~500 voxels were defined in the auditory, visual and left motor cortices based on the 2D-EPI GLM results. From each ROI, timecourses were extracted, temporally filtered to remove slow drifts and subsequently temporally reordered relative to the stimulus onset. Time to BOLD peak was calculated after low-pass filtering of the reordered timecourses.

Results and Discussion Multisensory facilitation was evident from the reaction times, with significant differences ($p < 0.001$) between AV and both A and V stimuli (Fig 1). Maximum t-scores per cluster were $120 \pm 30\%$ higher for the 3D-EPI-CAIPI acquisitions than for the corresponding 2D-EPI acquisitions due to the larger number of datapoints (Fig.2).

ROI timecourses averaged over runs and subjects are shown in Fig 3 for the visual cortex (3a/d), auditory cortex (3b/e) and motor cortex (3c/f). Positive responses for auditory stimuli were found in the visual cortex and vice versa, albeit significantly delayed compared to the cortex-own stimuli (Table1). BOLD responses to the AV stimulus were of the slightly smaller amplitude than the A/V stimuli in all ROIs, and occurred earlier than either of the single-input stimuli (Table 1). This difference was not measurable in the TR=2 data, as can also be concluded from Fig3d-f.

Conclusion The high temporal resolution provided by 3D-EPI-CAIPI allows the detection of subtle changes in hrf dynamics, as occur during multisensory facilitation.

References [1] Feinberg and Setsompop, 2013, JMR, [2] Narsude et al, 2013, MRM, [3] Narsude et al, 2013, proc ISMRM, [4] Martuzzi et al, 2007, Cereb Cortex

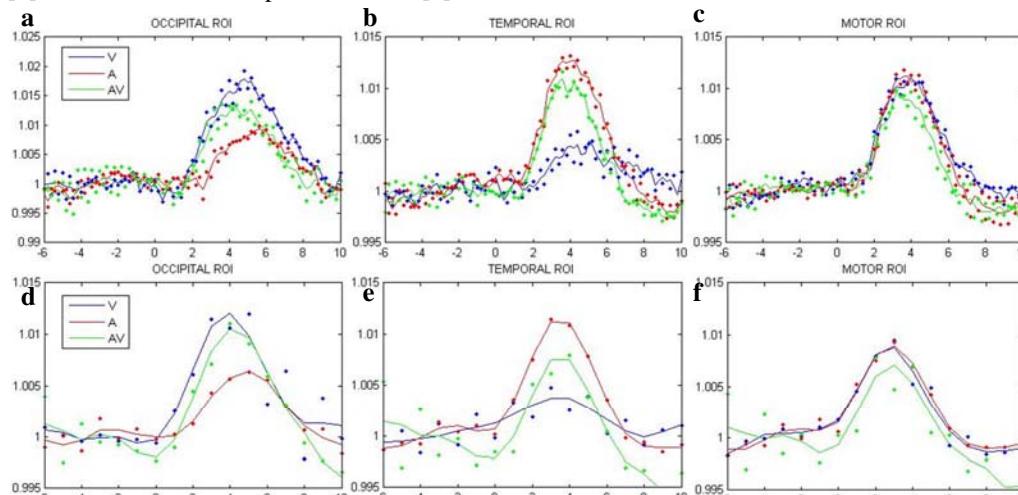


Fig 3 3D-EPI-CAIPI timecourses (TR=400ms, a-c) and 2D-EPI timecourses (TR=2, d-f) in occipital(a,d), temporal(b,e) and motor(c,f) cortices for V/A/AV stimuli. Continuous lines show lowpass filtered data, dots the unfiltered original.

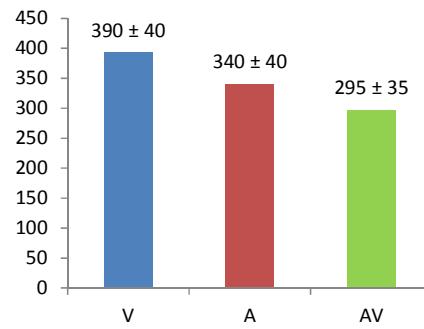


Fig 1. Average reaction times to V, A and AV stimuli. \pm stderr over runs and volunteers.

Time to peak 3DEPI CAIPI	V	A	AV
Occipital	5.0 s	5.8 s	4.4 s
Temporal	5.2 s	4.4 s	3.8 s
Motor	4.2 s	3.8 s	3.4 s
TTP EP2D			
Occipital	5s	6s	5s
Temporal	5s	4s	4s
Motor	4s	4s	4s

Table 1. Time to peak for A/V/AV responses in occipital, temporal and left motor ROIs.

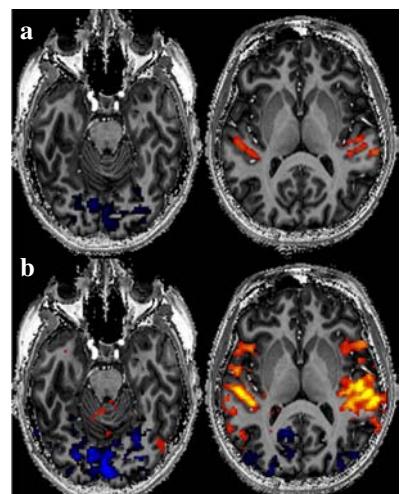


Fig 2. Slices from t-score maps (scale 3-10) of an example volunteer for (a) 2D-EPI and (b) 3D-EPI-CAIPI data. Red/yellow: A>V, blue V>A