

Imaging Cognitive Latencies with Ultrafast 7T fMRI

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Introduction

fMRI at high field (7 Tesla) benefits from higher SNR and greater BOLD contrast, and these have in general been used previously to improve the spatial resolution or sensitivity for detecting neural activation. However, the greater BOLD signals at 7T may also be exploited to increase the temporal resolution dramatically while maintaining the spatial resolution comparable to lower fields. Here we demonstrate how a modified 3D acquisition with relatively high SENSE factors at 7T can be used to acquire nearly full brain fMRI images with reasonable spatial resolution (3.5x3.5x6mm voxels), extremely short volume acquisition times (124ms), and still retain high BOLD contrast. We also show the potential for these sequences to resolve differences in response latency on timescales relevant for cognitive processing, by showing timing differences between visual and motor regions of the brain in a simple reaction time task.

Methods

(*TASK*) The subject viewed an 800ms radial checkerboard stimulus, scheduled in a rapid event-related design according to a binary m-sequence (Buracas & Boynton, 2002), and responded to each presentation as quickly as possible with a button press using the right index finger. The m-sequence period was 1.736s, with 32 stimulus repetitions scheduled per functional run. Four runs were acquired, for a total scan time of roughly 10min. (*IMAGING / PRELIMINARY ANALYSIS*) Each run consisted of 1050 axial images acquired on a Philips Achieva 7T scanner with a volume transmit and 32 channel parallel receive coil array. A 3D gradient echo sequence was used in combination with both small echo-planar readouts in the right/left direction (19 lines/shot) and echo shifting gradients for faster imaging with the following parameters: TR/TE=15.5/23.84ms, flip=10°, SENSE factors (in/through plane) = 3.8/2.5, FOV= 220x220x84mm. Voxel dimensions were 3.5 x 3.5 x 6mm respectively, and each volume required 124ms to acquire. All functional images were motion corrected, spatially smoothed (6mm FWHM), temporally lowpass filtered (0.8Hz), linearly and quadratically detrended, and normalized to percent signal change units relative to the mean signal intensity for that run. A finite impulse response (FIR) general linear model design matrix (Dale, 1999) was constructed out of a series of delta functions at a range of lags relative to stimulus onset, ranging from 1.984s (16 dynamics) prior to onset to 15.996s (129 dynamics) after onset. This allowed for detection of event related responses of different lags from voxel to voxel. Effect size and significance of activation at each time point were calculated relative to the average of the 16 prestimulus baseline time points. (*TIME COURSE ANALYSIS*) The first voxels within visual and motor cortex exceeding a $p < 0.005$ (uncorrected) significance value were identified in both visual and motor areas and defined as regions of interest (ROI). Time courses were generated for each ROI by first averaging together all voxels within each ROI (prior to percent signal normalization, but subsequent to all other preprocessing steps), then fitting the same GLM as described previously to the resulting ROI-average time series data. The resulting effect size time courses show the estimated response within an ROI to a single visual presentation and the corresponding button press.

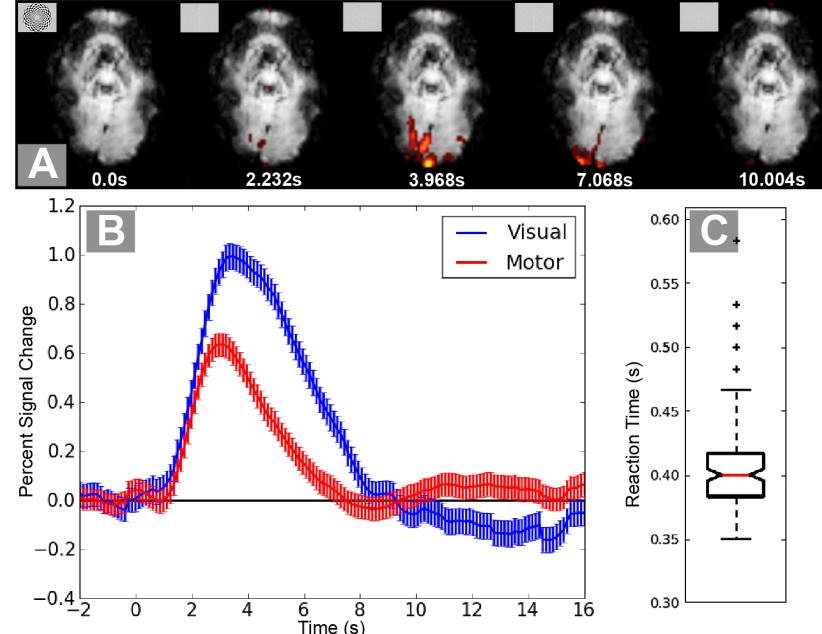


Fig 1: [A] An illustration of the temporally resolved activity in the visual cortex: Time relative to stimulus presentation is shown underneath each image. The state of the stimulus at each time point is shown to the top right of each image. [B] The mean event related responses measured in the visual and motor cortices: Note the apparent temporal lag between the visual and motor responses. [C] The distribution of response times measured via button presses: The red line marks the median, the box marks the 25th/75th quartiles, whiskers mark the range of the data excluding outliers, and outliers are marked individually.

Results

Significant, temporally resolved, event related activity was measured in both the visual and motor cortices. An example from the visual cortex can be seen in Figure 1A. Among significantly active voxels in the visual cortex, the first activations occurred bilaterally 1.488s after stimulus onset (25 voxels total), while the first activations in the motor cortex occurred in the left hemisphere 1.736s after stimulus onset (seven voxels total). This represents an average latency of 248ms between activity in the two regions, which can be seen in Fig. 1B as a relative shift in their event related time courses. The median response time measured via button press was 400ms, and the distribution of response times can be seen in Fig 1C.

Discussion

Here we have demonstrated the potential of ultrahigh field fMRI to resolve latency differences between distant regions of the brain. The acquisition described here shows that it is possible to image with extremely high temporal resolution (124ms) while maintaining nearly full brain coverage and reasonable spatial resolution (3.5x3.5x6mm voxels). While validated in an experiment inducing known timing differences, future studies may use acquisitions like this to measure unknown latencies between similarly distant regions of the brain.

References

Buracas et al, 2002. *NeuroImage*, 16(3 Pt 1), pp.801-813.
Dale, A.M., 1999. *Human Brain Mapping*, 8(2-3), pp.109-114.

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