Does the BOLD response to EPI-related acoustic noise change over an fMRI experiment?

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Introduction: Echo-planar imaging (EPI) is by far the most commonly used method for human functional neuroimaging. EPI measures changes in a blood oxygenation level dependent (BOLD) signal over a fairly large volume with fairly high spatial and temporal resolution. To achieve this, alternating magnetic field gradients must be applied as rapidly as possible, which dictates that the EPI pulse sequence is accompanied by a continuous, loud acoustic noise. It has been shown that EPI acoustic noise produces a significant BOLD response in auditory areas [1].

The BOLD response induced by acoustic noise can interfere with measurement of neural activation in regions responsive to auditory stimuli. If EPI-induced activation is constant over the course of an experiment, its effect can be discounted using standard fMRI analysis techniques. However, if the neural or hemodynamic response to the acoustic noise changes as the experiment progresses, fMRI experimental results could be affected. In the case of a standard speech or auditory neuroscience experiment, the additional fMRI time series noise will reduce the statistical power of the experiment (increasing type II errors), while in experiments probing auditory learning [2] a consistent temporal change in auditory BOLD could lead to a statistically significant—but spurious—result (increasing type I errors). In this study we used single voxel functional spectroscopy (FS) to measure the BOLD response to EPI-like acoustic noise in a brain region involved in auditory attention over a time course similar to that of a standard fMRI experiment, which is possible because FS acquisitions produce very little acoustic noise.

Methods: Four subjects were scanned using a 1.5 T Avanto system and a 32-channel head coil (Siemens Healthcare, Erlangen, Germany). An initial functional localizer task (described elsewhere, [2]) was performed to locate a brain region involved in auditory attention. Whole-brain EPI volumes were collected while the subject performed the task (TR=2s, TE=40ms, BW=2298Hz/px, 64x64 matrix size, FOV=208mm^2, 32 slices, 3.6mm slice thickness, 160 measurements). Just after imaging, the resulting volumes were analyzed using FSL to reveal voxels more active during auditory attention than visual attention. A cluster of voxels in the posterior and superior portion of the Sylvian fissure were located and used as a guide to position a volume of interest (VOI) in an auditory attention-related brain region (Figure 1).

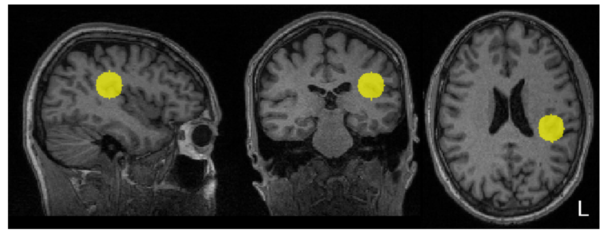

Figure 1: VOI placement in an auditory attention region

A custom pulse sequence was designed and implemented to measure BOLD activation in the VOI silently while also switching magnetic field gradients to create EPI-like acoustic noise between FS acquisitions. The gradient switching could be turned on and off to create a “block design” alternating between EPI-like acoustic noise and silence. Activation from the VOI was measured continuously using FS [3], which consists of a PRESS sequence for single-voxel spectroscopy without water signal suppression and with reduced gradient slew rate to minimize acoustic noise. Changes in T2* due to neural activation result in changes in the free induction decay (FID) signal measured using FS, which provides a method for measuring VOI BOLD with almost no acoustic noise. Our imaging parameters for the FS were: TR=2.39s, TE=41ms, VOI size=20x20x20mm^3, vector size=1024, BW=2300Hz.

Each subject performed 50 blocks in 10 runs over about 40 minutes. Each block consisted of 1TR of actual EPI acquisition for online head motion correction (Siemens PACE), followed by 8 TRs with EPI-like gradient switching on (noise condition), followed by 1TR of actual EPI image collection for motion correction, followed by 8TRs of no gradient switching (silent condition). FS FIDs were collected on each TR regardless of condition. VOI BOLD magnitude was measured by integrating the FID measured at each TR after receive coil combination that included noise reduction via a singular value decomposition of the FIDS (rearranged to represent coil signal by time) to eliminate common-mode white noise.

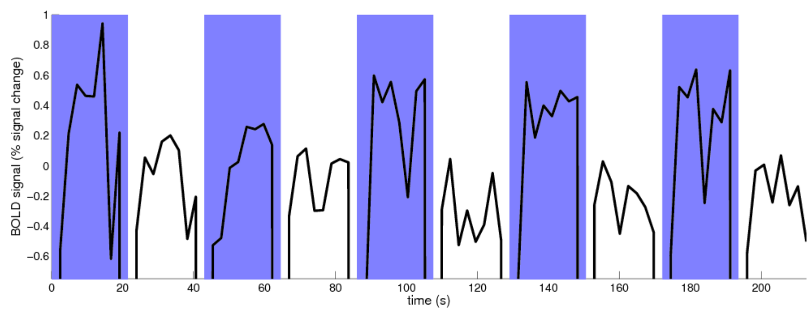

Figure 2: VOI BOLD time series from a single run. Blue blocks had EPI acoustic noise.

Results and Discussion: There was significant activation in response to the EPI-like acoustic noise for each subject (*t*-test for mean difference between adjacent noise and silent blocks). Figure 2 shows the BOLD signal change over a single run for one subject. There is a substantial difference in BOLD magnitude between noise (blue) and silent (white) blocks. The sharp drops in the signal at block boundaries are due to the excitation pulse of the EPI applied only at those TRs, which are required to acquire volumes for use in motion correction. The BOLD response in each of the 50 blocks was computed for each condition as the FID area over the last 6TRs of the block (2 were skipped to account for the hemodynamic lag). The BOLD response to the noise in each block was computed as the difference between the BOLD signal in the noise block and the silent block that followed immediately afterward. This results in a 50 data-point time series for each subject representing the evolution of VOI BOLD response to EPI-like acoustic noise over 40 minutes (similar to the length of EPI acquisition during a standard fMRI experiment).

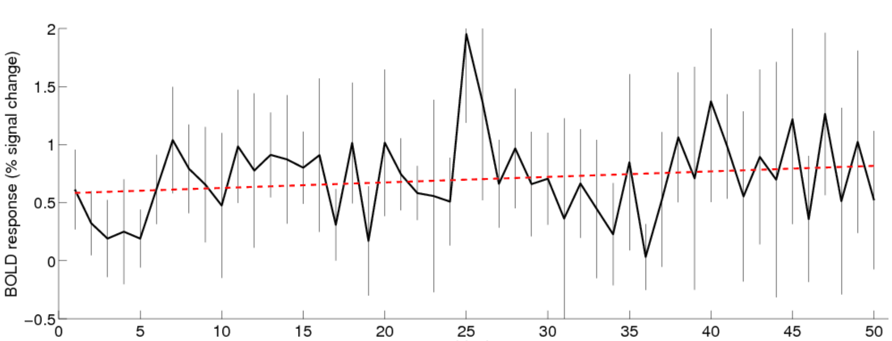

Figure 3: BOLD response over time for all subjects. No significant trends were found.

An ANOVA was conducted across subjects to determine if there was significant change in BOLD response to EPI-like noise over the experiment. There was no effect of block number ($F(3,49) = 0.88$; $p=0.695$), which indicates that BOLD response to EPI noise does not change significantly over an fMRI experiment in this VOI. A regression on the mean BOLD response over block also showed no trend ($r^2=0.03$, $p=0.18$). The BOLD time series over the group of subjects is shown in Figure 3, with the regression shown in the red line (error bars are standard error). At least for this auditory attention region, no significant habituation to EPI noise occurs, which validates the results of previous auditory fMRI experiments. Future work will determine if primary auditory regions exhibit the same behavior.

References: [1] Bandettini, et al1998. MRM 39, 410-416 [2] Thompson, et al., 2009. HBM Abstract #22 F-PM [3] Hennig, et al., 1994. MRM 31, 85-90

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