Using local field potential information instead of the block design model for BOLD analysis

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Introduction

Conventionally, the block design model function has been used as a model for BOLD signal time course in fMRI analysis. Simultaneous local field potential (LFP) and functional magnetic resonance imaging measurements provide unique premise to use the information measured directly from the brain as the model of the BOLD signal, which may provide insight to neurovascular coupling. The aim of this study was to assess to what extent the deviations of neuronal activity from that assumed in the block design model explain the inter-animal variation typical for many experimental fMRI settings.

Materials and Methods

A tungsten wire electrode was inserted to the right somatosensory cortex of a rat (n=14, 319 ± 14 g). Most of the methods are described in more detail in [1]. Urethane (1.25 g/kg, i.p.) was administered after the isoflurane anesthesia for the surgery was discontinued. The signal from the electrode was amplified, band-pass filtered and resampled at 1 kHz. The MRI experiments were performed in a 4.7 T horizontal scanner interfaced with a Varian UnityInova console. Based on sagittal pilot scans, the functional imaging slice was positioned coronally to the somatosensory cortex at bregma within 1 mm of the electrode. FMRI data were acquired using a single-shot spin-echo echo-planar-imaging sequence (TR 2 s, TE 60 ms, thk 1.5 mm, FOV 2.5 cm, 64 × 64). Electrical stimulus to the left forepaw of the rat was delivered at 10 Hz. fMRI data were collected with 60 s baseline followed by 30 s electrical stimuli to the forepaw, which was then repeated three times followed by 60 s baseline at the end of the experiment (total 165 images). Data were analyzed with the SPM5-program along with in-house made Matlab-code. Data are presented as mean ± SEM. Within 40 ms of each stimulus, the lowest negative evoked response peak was identified and the LFP model was calculated as a sum of these evoked responses for 2 s intervals. The LFP model was then convoluted with the 10 s long gamma function to account the delay between stimuli and the onset of BOLD response.

Results

The number of activated pixels in the somatosensory cortex was statistically different in LFP model than with the block design model (paired t-test, $p<0.05$), the number of pixels being 15.4 ± 2.6 and 12.8 ± 2.6 respectively. The number of activated pixels outside the somatosensory cortex was not statistically different in these models. Despite the difference in the number of pixels, the maximum BOLD signal was not statistically different in both of the models, maximum BOLD signals being 5.3 ± 0.7 % and 5.0 ± 0.9 % in LFP and block design models, respectively. In all three cases when there was no detectable BOLD activation with the block design model, the LFP model predicted activation in the somatosensory cortex (Fig 1 C).

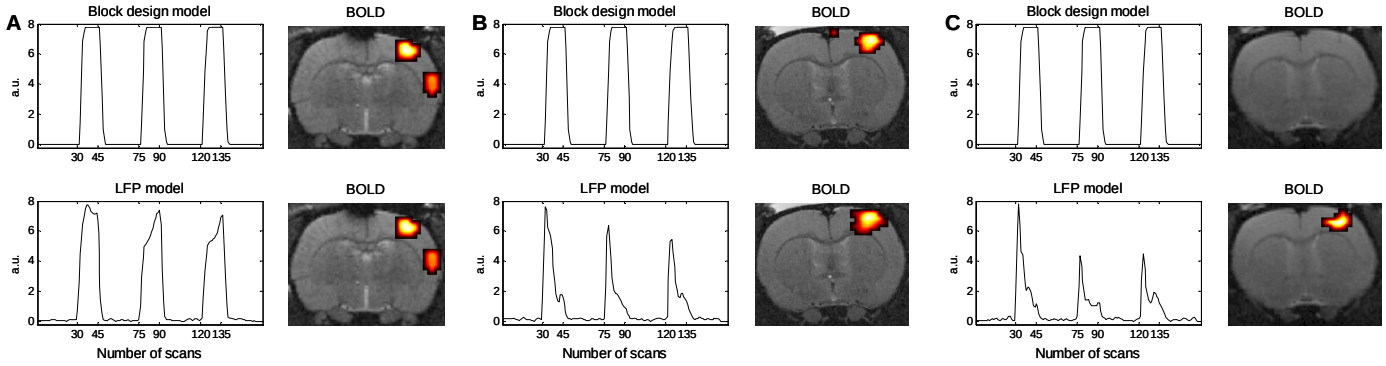

Figure 1. Three representative rats with different LFP models. BOLD activations are overlaid on anatomical spin-echo images. **A**. LFP model is similar to the block design model, and number of activated pixels in BOLD is similar. **B**. The LFP model differs from the block design model and the activated area is a larger with the LFP model. **C**. The LFP model disagrees with the block design model, and only the LFP model predicts activation in the somatosensory cortex.

Discussion

Our data further confirm the strong coupling between neuronal activity and BOLD response. It is commonly known, but seldom reported, that a small fraction of the animals does not produce measurable BOLD response to stimuli in many experimental settings. Our data show that this is likely because of the different activation pattern in the neuronal level, rather than due to incomplete neurovascular coupling. However, in the vast majority of the cases, the block design model seems to provide good approximation of the neuronal response and thus both the activated area and maximum BOLD response did not differ between the two approaches.

Reference [1] Huttunen, J. K., et al., NeuroImage (2007), doi:10.1016/j.neuroimage.2007.06.042