Robust detection of functional activation in the superior colliculus without ECG-triggering

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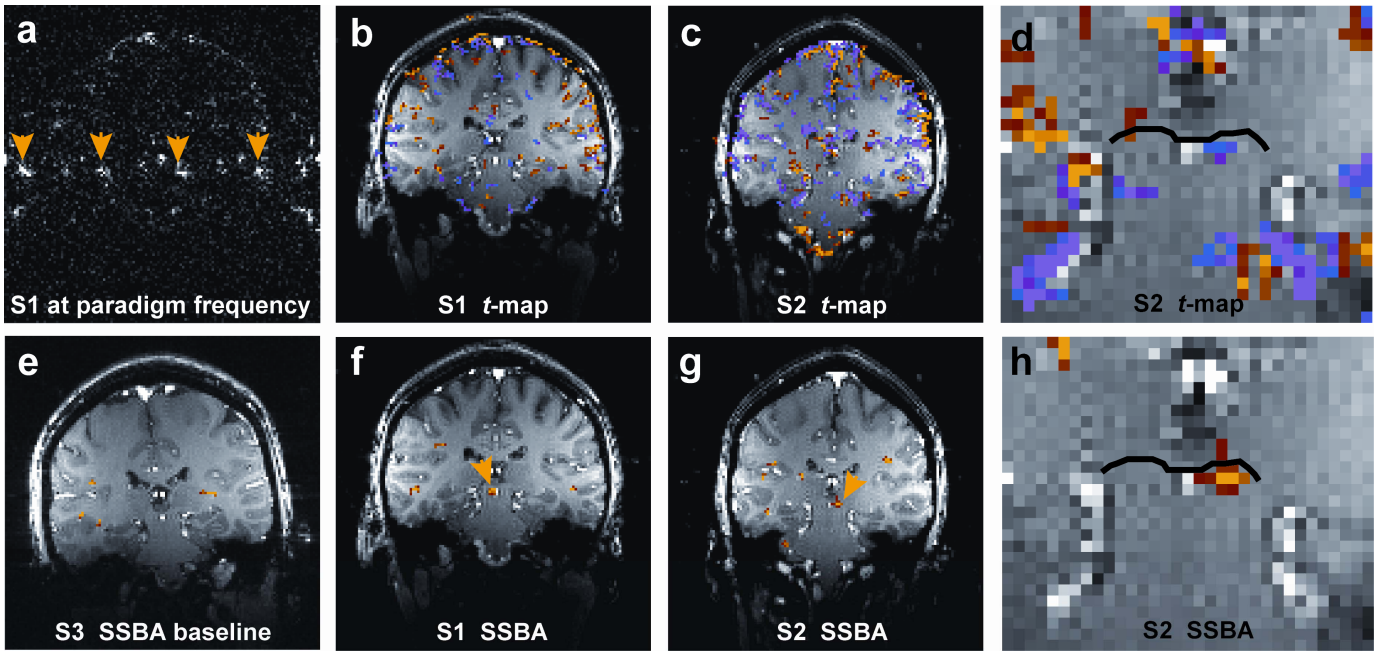
Introduction: For fMRI with high spatial resolution, segmentation of the echo-planar imaging (EPI) acquisition is often employed. However, such images are susceptible to ghosting due to pulsatile flow of blood and cerebrospinal fluid (CSF), especially in regions near the brain stem. In a previous high-resolution fMRI study of the superior colliculus (SC), ECG-triggering was used to reduce physiological signal fluctuations [1]. We propose a novel post processing technique, the spectral side band analysis (SSBA), to detect activation in the SC without the need of ECG-triggering.

Methods: Experiments were performed on a 7 T Siemens scanner using an in-house built 16 channel transmit/receive array coil. Three subjects were scanned after written consent. Eight runs of 10 blocks of the 15 s flickering checker board and 15 s of rest were presented to two subjects. In the third study, baseline data without stimulation were acquired using the same protocol as for the two stimulation study. For the functional part, a 4 segmented Hahn spin echo EPI sequence was used with a matrix size of 128x128, FOV 192x192 mm^2, slice thickness 2 mm, echo time: 55 ms, repetition time 3 s. 6 coronal slices were acquired covering the SC. No ECG-triggering was used. All eight functional runs were averaged.
A data set based on the same imaging parameters and amplitude modulated with the expected blood oxygenation level dependent (BOLD) response was simulated. SSBA is based on Fourier transforming the complex image time series along the temporal coordinate rendering a pseudo-spectral coordinate for each voxel. Based on the simulation, frequency and phase of the stimulus-related ghosts at the fundamental frequency of the paradigm was used to detect the BOLD response.

Results:



Top row: (a) Spatial magnitude signal distribution at the fundamental frequency of the paradigm in Subject 1 (S1). Significant ghosting of CSF (arrows) is visible. **(b)** and **(c)** *t*-maps (color-code: $1.2<t<3.0$) of subject 1 (S1) and 2 (S2). No activation is seen in SC in S1 and negative activation in S2 despite a very low threshold. **(d)** shows a magnification of the SC in **(c)**. The curved black line indicates the superior edge of SC. **Bottom row: (e)** to **(h)** show the activation maps (color-code: amplitude of signal modulation at the fundamental frequency of the paradigm) obtained with SSBA. The same threshold [arbitrary units] was used for all subjects. **(e)** Baseline data (no stimulation) of subject 3 (S3). No activation is found in the SC. **(f)** and **(g)** show activation in SC in S1 and S2 (arrows). Maps obtained with SSBA of the same data sets as in **(b)** and **(c)** are much less noisy than the corresponding *t*-maps. **(h)** shows the magnified SC in **(g)**. The black line marks the upper edge of the SC. The one-sided activation of SC in S1 and S2 might be caused by the limited coverage of the visual field by the projection system.

Discussion: Using the spectral side band analysis, the BOLD response can be recovered from segmented EPI data which are severely affected by ghosting due physiological noise without ECG-triggering. This has been demonstrated in a high resolution fMRI study of the superior colliculus.

References and acknowledgments: [1] Schneider KA, Kastner S, J Neurophysiol 94: 2491 (2005)
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