High temporal resolution and physiological noise removal improve BOLD detection in brainstem and auditory cortex at 7T

Wietske van der Zwaag[1,2], Mayur Narsude[1], João Jorge[3], José Pedro Marques[1,2], and Rolf Gruetter[1,2]

[1]Université de Lausanne, Lausanne, VD, Switzerland, [2]LIFMET, EPFL, Lausanne, VD, Switzerland, [3]Instituto Superior Técnico, Lisbonne, Switzerland

Introduction Physiological noise often dominates fMRI timecourses at ultra-high field, reducing the BOLD sensitivity. The brain stem region is especially affected because of the heart rate associated motion. Regions closer to the skull, such as the primary auditory cortex (AI) are much less affected. The ratio of thermal/physiological noise can be modified by changes in sequence parameters, notably spatial resolution. There are also efficient methods for physiological noise removal, typically based on acquistision of physiological traces (RETROICOR) or an extra resting-state data set[1]. A high temporal resolution can also aid BOLD detection if the cardiac and respiratory rhythms are no longer undersampled.

3D-EPI has the benefit over standard 2D-EPI that acceleration in the slice-dimension can be used to shorten the volume acqusition time T_{vacq}. Besides partial Fourier sampling and parallel imaging, T_{vacq} can be further shortened by acquiring 2 or more segments after a single excitation. Although 3D-EPI is more sensitive to physiological noise than its 2D equivalent[2] due to the longer signal averaging time, it has been shown that after appropriate physiological noise removal, the BOLD senstivity is higher than for 2D-EPI[3]. Here, the high temporal resolution of 3D-EPI is used in combination with physiological noise removal to detect activation in the brainstem during presentation of environmental sounds.

Methods Five volunteers were scanned on a 7T scanner (Siemens Medical Solutions, Germany) with an 8-channel Tx/Rx rf-coil (Rapid Biomedical GmbH, Germany). Subjects were asked to attend to 5s environmental sounds interspersed with 15s silence during two 5-minute activation runs. 2 identical rest runs were acquired without stimulation. The 1.5*1.5*1.5 mm^3 resolution fMRI data were acquired using 2D and 3D-EPI sequences[2] with FOV=192*192*60mm, TE=28ms, GRAPPA=2, BW=2604Hz/px. 2D:TR=1.83s,α=60(SAR limited), 164 volumes. 3D-1(1 plane sampled per excitation): TR=2s, α=17,partial fourier (pf) 6/8 in phase and slice dimension, 150 volumes. 3D-2(2 planes sampled per excitation): TR=1s, α=17,pf 6/8+6/8, 300 volumes. Each volume contained 40 axial slices covering the entire planum temporale as well as the brainstem. For three subjects, 2D and 3D-2 EPI runs were compared, for another three subjects (1 overlap) the standard 3D-EPI and the 3D-2 EPI. The order of rest/act runs was counterbalanced across subjects. 1-mm^3 anatomical data were acquired using the MP2RAGE sequence[4] (TE/TI$_{1,2}$/TR$_{mprage}$ = 3.75ms/0.7,2.2s/5s).

Data analysis was done using SPM and involved the following steps: realigment, smoothing (FWHM 2mm), coregistration of MP2RAGE and EPI. All data were analyzed with and without a PCA-based physiological noise removal method[1,3] using data from the rest runs.
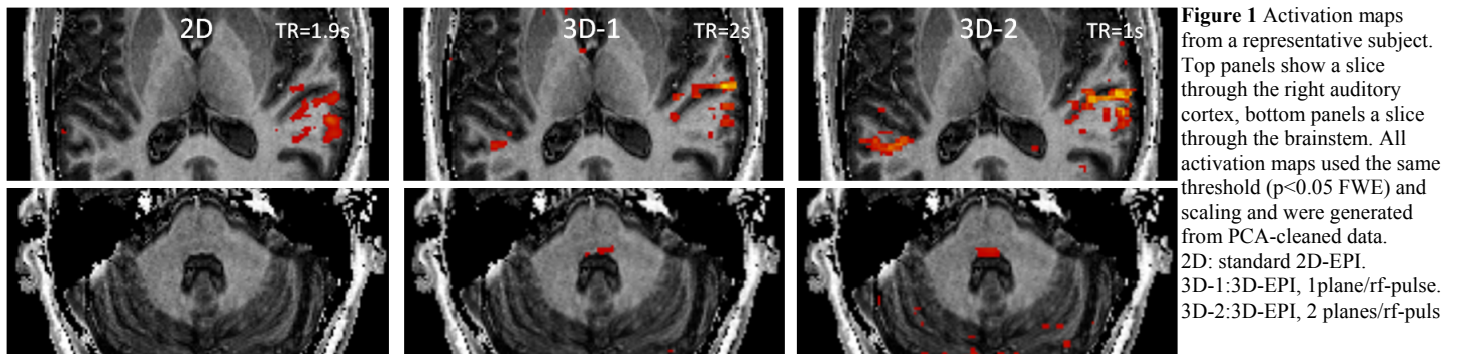

Figure 1 Activation maps from a representative subject. Top panels show a slice through the right auditory cortex, bottom panels a slice through the brainstem. All activation maps used the same threshold (p<0.05 FWE) and scaling and were generated from PCA-cleaned data. 2D: standard 2D-EPI. 3D-1:3D-EPI, 1plane/rf-pulse. 3D-2:3D-EPI, 2 planes/rf-puls

Results All subjects showed strong activation of AI for all activation runs. Examples of activation maps (p<0.05 FWE) for the subject which participated in both parts of the experiment are shown in Figure 1. Slices through the right primary auditory cortex and the brainstem are displayed. Activation size as measured by number of activated voxels and statistical significance depended on acquisition method (2D/3D), volume acquisition time and physiological noise removal (Table 1). Activation in the brainstem was small and only present when physiological noise removal was used (Table 2). Higher temporal resolution resulted in the brainstem in larger active regions and higher statistical values, as in AI.

aud cortex	2D	3D-1	3D-2
# voxels no PCA clean	110±40	490±110	1700±300
# voxels PCA cleaned	200±60	1950±400	3600±400
max F-value no PCA	75±10	100±15	250±20
max F, PCA cleaned	125±30	240±30	546±37

Table 1 auditory cortex BOLD measures

brainstem	2D	3D-1	3D-2
# voxels no PCA clean	-	-	-
# voxels PCA cleaned	1	5±2	38±20
max F-value no PCA	-	-	-
max F, PCA cleaned	-	14±3	21±7

Table 2 Brainstem BOLD measures. Grouped over all auditory brainstem nuclei including the ic

Discussion and Conclusion Detection of BOLD signal changes in the brainstem benefits from high SNR, increased temporal resolution and physiological noise removal using a PCA approach. However, active regions remained small, probably due to the non-optimal slice orientation, required to cover both brainstem and auditory cortex and the lack of cardiac gating[5]. A further increase in temporal resolution could be obtained with an RF coil allowing parallel imaging acceleration in the z-direction.

References and acknowlegdements [1]Biancardi et al, 2009, Neuroimage. [2]van der Zwaag et al, 2011, MRM, [3]Jorge et al, 2011, ENBENG (6026092). [4]Marques et al, 2010, NeuroImage. [5]Guimaraes et al 1998, HBM. This work was supported by the Centre d'Imagerie BioMédicale of the UNIL, UNIGE, HUG, CHUV, EPFL and the Leenaards and Jeantet Foundations.