AUTOMATED SPECTRAL ASSESSMENT OF THE BOLD EFFECT FOR NEUROFEEDBACK AT 3 AND 7 T.

Yury Koush[1,2], Mark A. Elliott[3], Frank Scharnowski[1,2], and Klaus Mathiak[4,5]

[1]Department of Radiology and Medical Informatics - CIBM, University of Geneva, Geneva, Switzerland, [2]Institute of Bioengineering, École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland, [3]Center for Magnetic Resonance and Optical Imaging (CMROI), Department of Radiology, University of Pennsylvania, Philadelphia, Pennsylvania, United States, [4]Department of Psychiatry, Psychotherapy and Psychosomatics, RWTH Aachen University, Aachen, Germany, [5]Institute of Neuroscience and Medicine (INM-1), Research Center Jülich, JARA - Translational Brain Medicine, Aachen, Germany

<u>Purpose:</u> To date, conventional EPI-based fMRI is the only method capable of providing real-time neurofeedback from a spatially specific ROI. Alternatively, functional single voxel proton spectroscopy (SVPS) can be used to achieve spatially specific BOLD neurofeedback at 7 T [1]. The purpose of this work was to automatize and to evaluate this alternative approach by running real-time fSVPS experiments on high (3 T) and ultra-high (7 T) magnetic fields.

<u>Methods:</u> The water spectra full width at half maximum is back-proportional to the T2* changes and can be used as a marker of the BOLD effect[2]. In order to estimate T2* from the unsuppressed water spectra in real-time, we therefore implemented a fully automated single lorentzian non-linear complex spectra fit (LNLCSF) with the Levenberg-Marquardt fitting algorithm[3]. To evaluate this procedure, we assessed the SVPS T2* estimates of primary motor cortex (PMC) and visual cortex (VC) activity in real-time at 3 T and at 7 T by running standard finger tapping and flickering checkerboard experiments. In addition, we performed a neurofeedback experiment using the SVPS T2* estimate based on the optimized linear regression (OLR) approach as the feedback signal[1]. LNLCSF and OLR T2* time courses were compared across a group of 7 participants at 3 T (28±7 yrs) and at 7 T (33±9 yrs) in terms of the percent signal change and t-statistics.

SVPS target voxels were defined based on PMC and VC ROI coordinates which were localized by running standard functional localizers based on a single-shot gradient-echo T2*-weighted EPI sequence with 300 repetitions (TR = 1000 ms, 16 slices volumes, matrix size 64 x 64, voxel size = 3 x3 x 3.75 mm^3, flip angle α = 77°, bw = 2.23 kHz/ pixel, TE = 30 ms at 3 T, TE = 28 ms at 7 T). At 3 T, water spectra were acquired using a spin-echo SVPS protocol with 300 repetitions (TE/TR = 30/1000 ms, flip angle α = 90°, bw = 1 kHz, acquisition duration = 512 ms). At 7 T, acquisition protocol was slightly different, with TE = 20 ms, bw = 2 kHz, acquisition duration = 256 ms. Average SVPS voxel size was ~1 cm^3.

<u>Results & Discussion:</u> Our results showed that the automated real-time spectroscopy approach can reliably quantify T2* changes from the unsuppressed water peak (Fig. 1), and that it is feasible at 3 T and at 7 T. PMC and VC areas showed comparably high percent signal changes and comparable t-values of the T2* time courses estimated with LNLCSF and OLR at 3 T ($\Delta\%_{OLR}$ = 4.1±1.8, $\Delta\%_{LNLCSF}$ = 3.9±1.4; t_{OLR} = 32.3±7.4, t_{LNLCSF} = 28.2±7.9, $p < 0.05$). At 7 T, LNLCSF approach showed lower percent signal changes and lower t-values than OLR ($\Delta\%_{OLR}$ = 4.4±2.2; $\Delta\%_{LNLCSF}$ = 1.7±1.1; t_{OLR} = 20.9±10.3, t_{LNLCSF} = 16.3±9.8, $p < 0.05$). At 7 T, the LNLCSF T2* estimation was biased by the single lorentzian assumption, but the advantage compared to OLR is that this approach is fully automated. The lower percent signal changes that we observed for the 7 T spin-echo acquisitions can be also due to the dominant microvasculature contributions[4].

<u>Conclusions:</u> We successfully automatized real-time water SVPS and showed that this new approach is of sufficient quality for neurofeedback purposes, which might lead to important scientific and clinical applications.

<u>Acknowledgements:</u> This study was supported by the DFG (MA2631/4-1, IRTG1328) and NIH (RR02305).

<u>References:</u>

1. Koush Y, et al. Single Voxel Proton Spectroscopy for Neurofeedback at 7 Tesla. Materials 2011; 4: 1548-1563.
2. Zhu X, and Chen W. Observed BOLD Effects on Cerebral Metabolite Resonances in Human Visual Cortex During Visual stimulation: A Functional 1H MRS Study at 4 T.Magn Reson Med 2001; 46: 841-847.
3. van den Boogaart, et al. Time and Frequency Domain Analysis of NMR Data Compared: An Application to 1D 1H Spectra of Lipoproteins. Magn Reson Med 1994; 31: 347-358.
4. Ugurbil K, et al. Ultrahigh field magnetic resonance imaging and spectroscopy. Magn Reson Imag 2003; 21: 1263-1281.

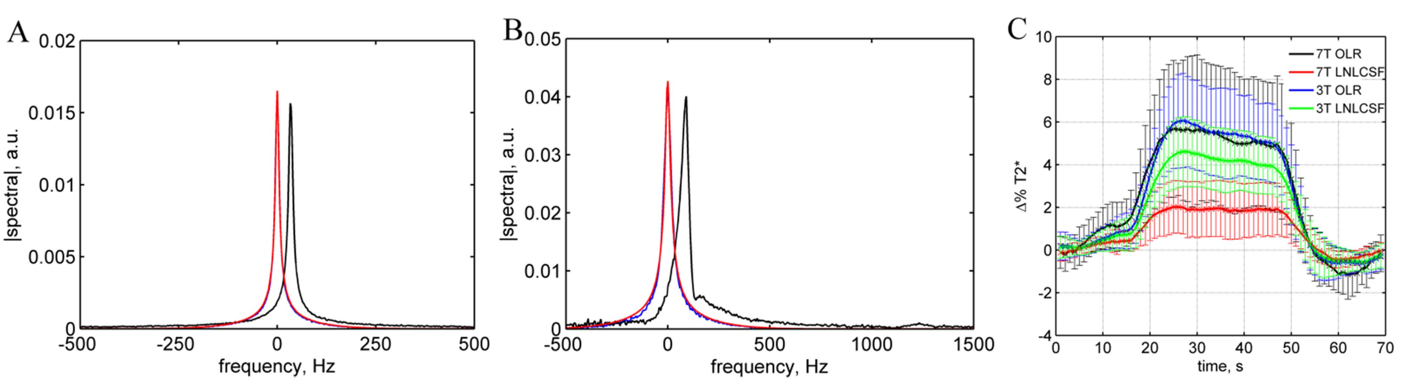

Figure 1: Real-time automated spin-echo SVPS assessment of the T2* changes at 3 T (A) and at 7 T (B). Original spectra (black) were preprocessed (blue) and fitted (red). (C) Group average T2* percent signal changes at 3 and 7 T.