Acoustic noise control during auditory fMRI using a DSP system - first initial in vivo results

Daniel Güllmar[1], Markus Hädrich[1,2], and Jürgen R Reichenbach[1]

[1]Medical Physics Group / IDIR I, Jena University Hospital, Jena, Thuringia, Germany, [2]University of Applied Sciences Jena, Jena, Thuringia, Germany

<u>Introduction</u>: Acoustic noise cancellation (ANC) during fMRI has been previously reported as a promising tool to enhance experiments using acoustic stimulation [1]. However, publications investigating the different aspects of this technique, such as interference of stimulus with noise cancellation procedures, are rare. We implemented a template-based ANC system for online application (similar to [1,2]) and evaluated the effect of pausing adaptation of the algorithm during acoustic stimulation.

<u>Material and Methods</u>: We implemented a FilteredX normalized Leaky Least Mean Squares (FXnLLMS) algorithm presented recently [3] on a DSP developer board (ADSP-21369 EZ-KIT Lite). In addition, we employed two optical microphones (MO 2000, Sennheiser, Wedemark, Germany) and an MR compatible headset (Resonance Technology, Los Angeles, USA). The implemented algorithm continuously optimizes the attenuation by adapting filter coefficients independently for the left and right channel. We conducted fMRI measurements on a 3T whole-body MRI system (Tim Trio, Siemens Medical, Erlangen, Germany) using auditory stimulation with a single frequency tone (binaural, 722 Hz, 500 ms duration, inter trial interval 12 up to 21 s, event-related, directly generated using Presentation (Neurobehavioral Systems, Inc., Albany, CA)) at four different amplitude levels. Each amplitude level was applied 10 times in random order. The amplitudes were adjusted during an fMRI pilot scan in the same session without activating the ANC system, such that the volunteer was able to detect the two upper amplitudes, but unable to detect the two lower amplitudes. The relative amplitude levels were 0, -8, -16 and -24 dB. The experiment was performed with active noise cancellation twice: one experiment, in which the adaptation of filter coefficients was stopped during acoustic stimulation and one experiment with continuous adaptation. In a third experiment no active noise cancellation was applied. The switching of the adaptation was controlled by the stimulation PC by sending a TTL signal to the ANC system just before and after each auditory stimulus. Scan duration for each experiment was approx. 12 min (depending on the inter trial interval). fMRI data were processed using SPM8 (http://www.fil.ion.ucl.ac.uk/spm/software/spm8/) with standard procedure (registration, temporal realign, normalization, spatial smoothing 5 mm FWHM). The contrast vector was set to summarize all amplitude levels occurrence (0 dB + -8 dB + -16 dB + -24 dB) and a threshold of $p < 0.05$ (FWE) was set to evaluate the activation pattern. The parameters for the standard BOLD-contrast EPI sequence were as follows: FoV 192 mm, 64 matrix, TE 30ms, TR 3.01s, slice thickness 3 mm, 45 slices.

<u>Results</u>: Both experiments with stopping adaptation during stimulus presentation (Fig. 1) and with continuous adaptation (Fig. 2) show significant activation ($p < 0.05$, FWE) in the right auditory cortex (AC). No activation was found in the left AC with continuous adaptation. Without active noise cancellation, no activation was observed in AC (neither left nor right). Fig. 3 shows the fitted BOLD responses for the different amplitudes for the left [@ -46, -30, 6] and right [@ 62, -18, 6] AC. These responses reflect the hemispheric differences due to the lower HRF amplitudes observed for the left AC compared to the right AC. We suspect that this hemispheric asymmetry is a consequence of the different performances of the left and right speaker channel of the used headphone.

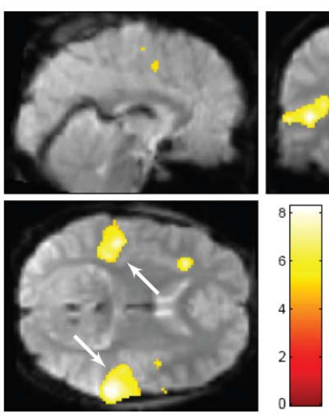

Fig. 1 Sectional view of the activation pattern for auditory stimulation obtained using active noise cancellation with stopping and starting adaptation during stimulus presentation. The arrows point to the left and right auditory cortex, respectively.

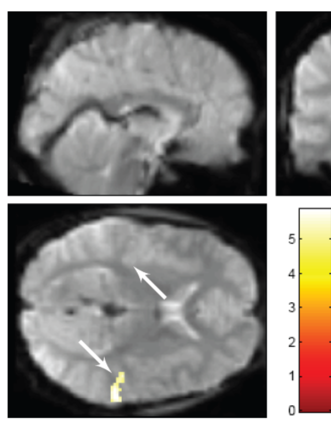

Fig. 2 Same as in Fig. 1, but with continuous adaptation during stimulus presentation. At a statistical threshold of p<0.05 (FWE) activation was only observed for the right AC which was substantially smaller compared to Fig. 1.

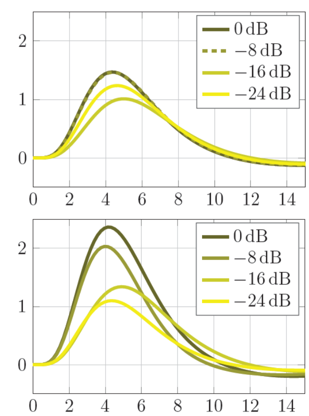

Fig. 3 Fitted responses for different amplitude levels for the left (upper graph) and right (lower graph) AC for the experiment using ANC with starting and stopping adaptation.

<u>Discussion</u>: Our fMRI experiment shows significant differences between continuously adapting noise cancellation compared to interrupted adaptation during stimulus presentation when using a self-developed real-time template-based noise-cancellation system. This finding may be the result that the algorithm attenuates the stimulus too quickly during stimulus presentation if adaptation is continuous. Currently, however, we cannot exclude that the increased background noise during stimulus presentation due to the interrupted adaptation is the source for the larger activation. Future works will evaluate techniques that aim to slow down the adaptation during the presentation of acoustic stimuli.

References:

[1] Hall DA, Chambers J, Akeroyd MA, Foster JR, Coxon R, Palmer AR. 2009. Acoustic, psychophysical, and neuroimaging measurements of the effectiveness of active cancellation during auditory functional magnetic resonance imaging. The Journal of the Acoustical Society of America 125 (1) p. 347-59

[2] Chambers J, Bullock D, Kahana Y, Kots A, Palmer A. 2007. Developments in active noise control sound systems for magnetic resonance imaging. Applied Acoustics 68 (3), p.281-295

[3] Güllmar D, Bitzer LA, Reichenbach JR 2011. Development of a Template Driven, Adaptive, Active Noise Cancellation (ANC) System for Reduction of MR Acoustic Noise – Initial Results. Proc Intl Soc Mag Reson Med 19 2011 p. 1797