# Auditory fMRI without an external stimulus: Using the gradient noise of an acoustically modified EPI sequence to stimulate the auditory cortex.

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**Introduction.** Recently, it was shown that LINA-EPI, an acoustically modified EPI sequence that produces continuous, unpulsed gradient noise, is capable of doubling the BOLD signal amplitude in the primary and secondary auditory cortex compared to conventional EPI [1]. Here we report that, by selectively re-introducing pulsating gradient noise into a LINA-EPI sequence, effective stimulation of the auditory cortex can be obtained without the need for an external stimulus. While using the MR scanner as a sound generator for auditory fMRI has been proposed before in the context of the sparse sampling technique [2, 3], LINA-EPI as a continuously sampling sequence has a much higher scantime efficiency and temporal resolution. In a simple 3-minute block design experiment, very pronounced activation was observed in the auditory cortex of a healthy volunteer using the new sequence.

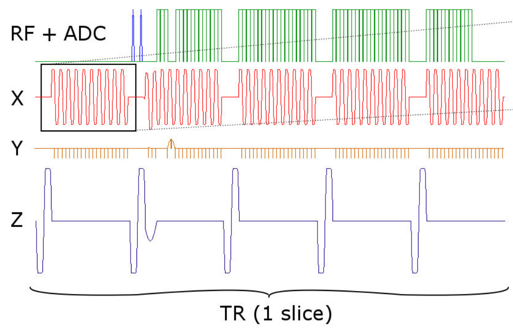


*Fig. 1a:* LINA-EPI sequence timing diagram for the acquisition of a single slice. The black frame indicates the additional gradients which here (for "stimulus off" case) serve to continue the unpulsed gradient sound of the sequence.

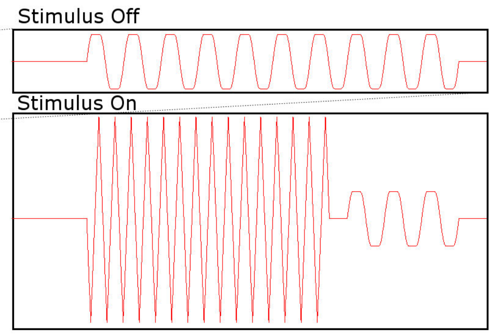


*Fig. 1b:* Enlarged plot of the additional block of x-gradients in figure 1a ("stimulus off"). For the stimulation periods ("stimulus on"), it is exchanged for a 15ms pulse of 1-kHz triangular gradients of maximum amplitude. To avoid eddy current induced artifacts, the last 7ms of both gradient patterns are identical.

**Methods.** The sequence here described is a modified LINA-EPI [1] sequence which introduces an additional block of gradients before the acquisition of each slice. These gradients match the "sound" of the image acquisition sequence for the stimulus-free periods (figure 1a) and are exchanged for a loud 1-kHz gradient waveform when acoustic stimulation is desired (figure 1b). The stimulus therefore is perceived as a loud pulse of sound repeated regularly at 1/TR (for one slice) during the stimulation period. To avoid eddy current induced stimulus-dependent artifacts (which could erroneously be interpreted as activation), the last 7ms of the gradient patterns are identical for the "stimulus on" and "stimulus off" periods. Water excitation using a 1-1 binomial RF pulse is employed to suppress the fat signal.

**Results.** A phantom experiment using a spherical water phantom showed no stimulus-dependent signal variation with a family wise error (FWE) $p<1$ (or uncorrected $p<0.001$). A seven-cycle block design experiment was conducted in a normal-hearing volunteer (9 slices, TR=1.261s, TE=52ms, 64x64 matrix, {10 volumes off, 10 volumes on, etc.}, total acquisition time 3:09min). Data was fitted to a fixed-effect GLM in SPM2 after standard preprocessing. Pronounced activation was obtained in the auditory areas (figure 2a). The BOLD time course in these activation clusters exhibits the expected temporal delay between the stimulation onset and the BOLD response (figure 2b), which, together with the localization of the activated cortical areas, clearly demonstrates that we indeed measured the BOLD effect in the auditory system and not a sequence induced artifact.

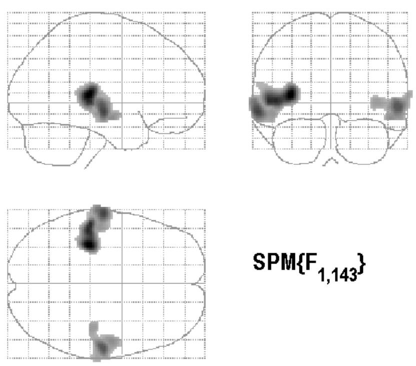


*Fig. 2a:* Bilateral activation in the auditory cortex of a volunteer (height threshold F=55.02, extent threshold 0, FWE $p<10^{-6}$). The activation clusters in this figure are used as volumes of interest for the time courses in figure 2b.

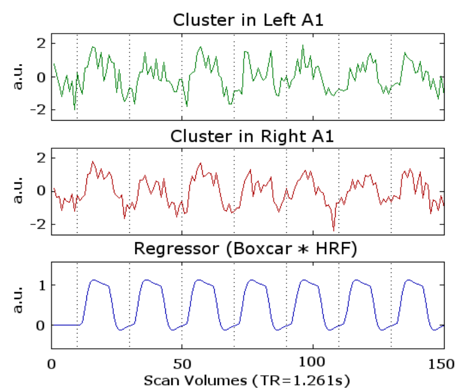


*Fig. 2b:* BOLD signal time courses in the activation clusters on the left and right hemispheres. The regressor is plotted to demonstrate that the signal rises with the expected BOLD delay rather than coinciding with the change from "stimulus off" to "stimulus on" (dotted lines).

**Discussion.** We are currently investigating the use of this sequence in pre-surgical functional assessments of tumor patients where we expect the simplicity of the stimulation scheme to be particularly beneficial. However, the sequence also lends itself to the simple and efficient investigation of a range of temporal and pitch dependent aspects of the BOLD response in the auditory system.

**References.**

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