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Rapid Communication

Enhancing BOLD response in the auditory system by neurophysiologically tuned fMRI sequence

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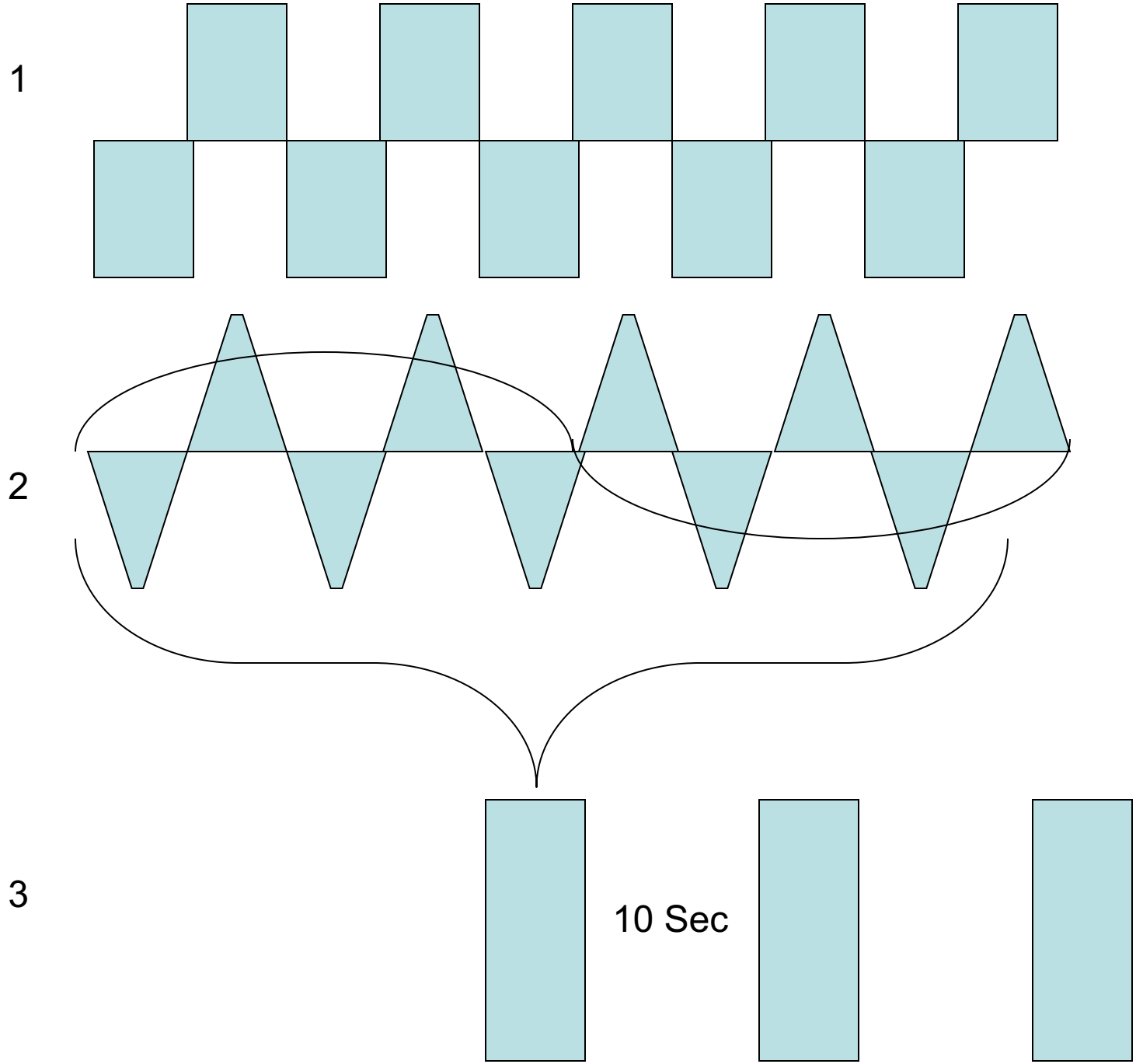
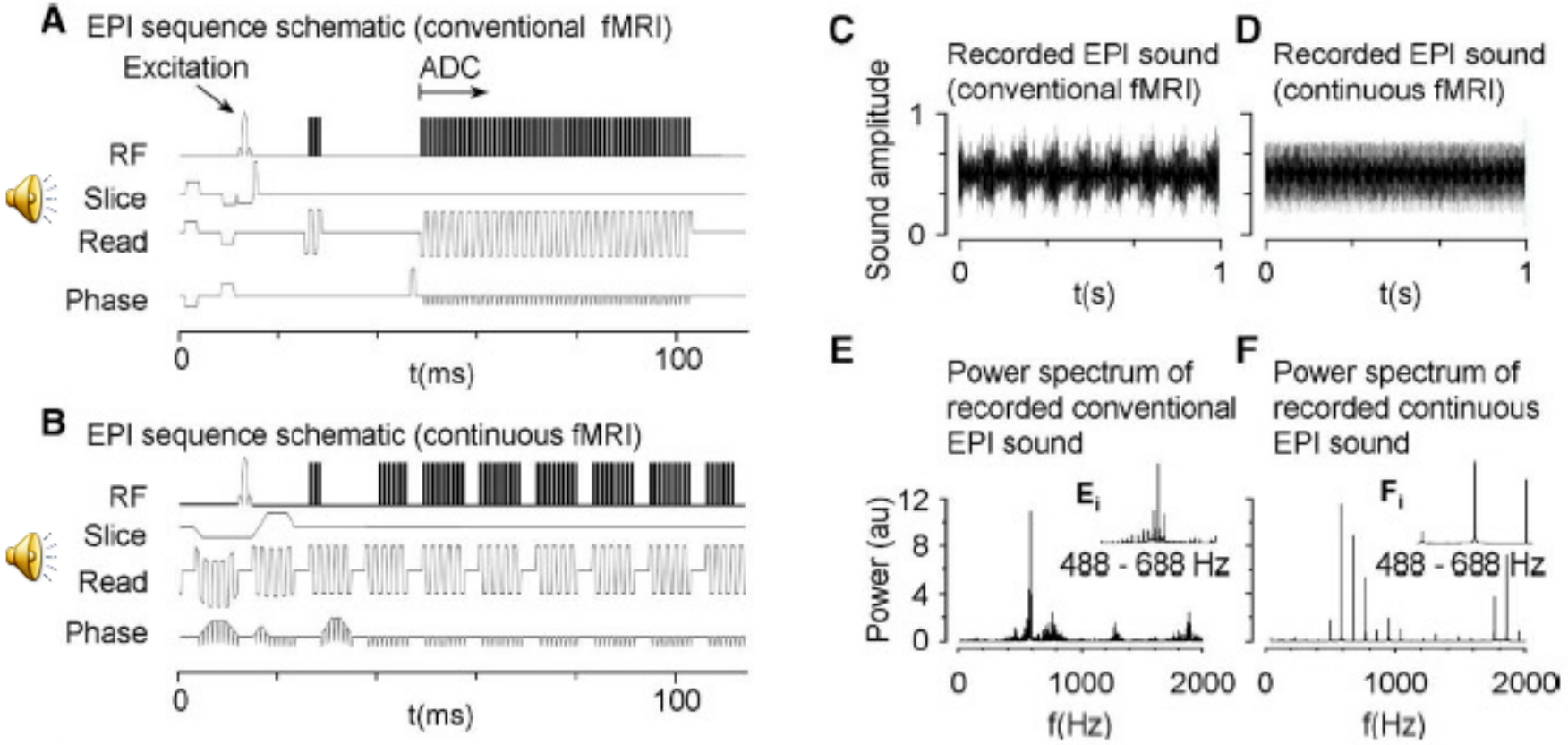
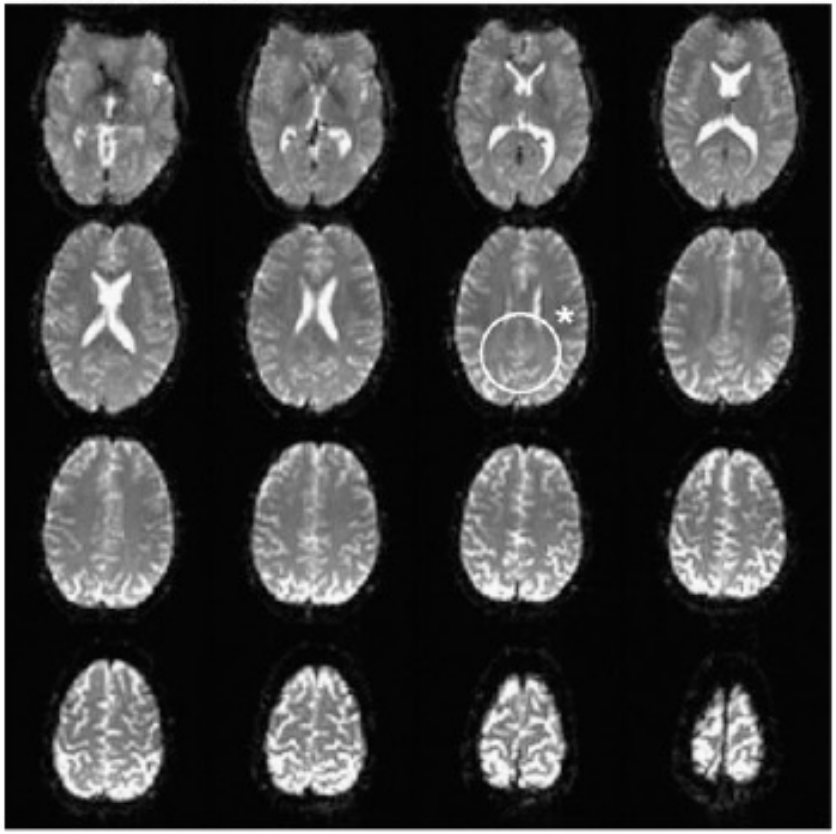

1
2
3
10 Sec

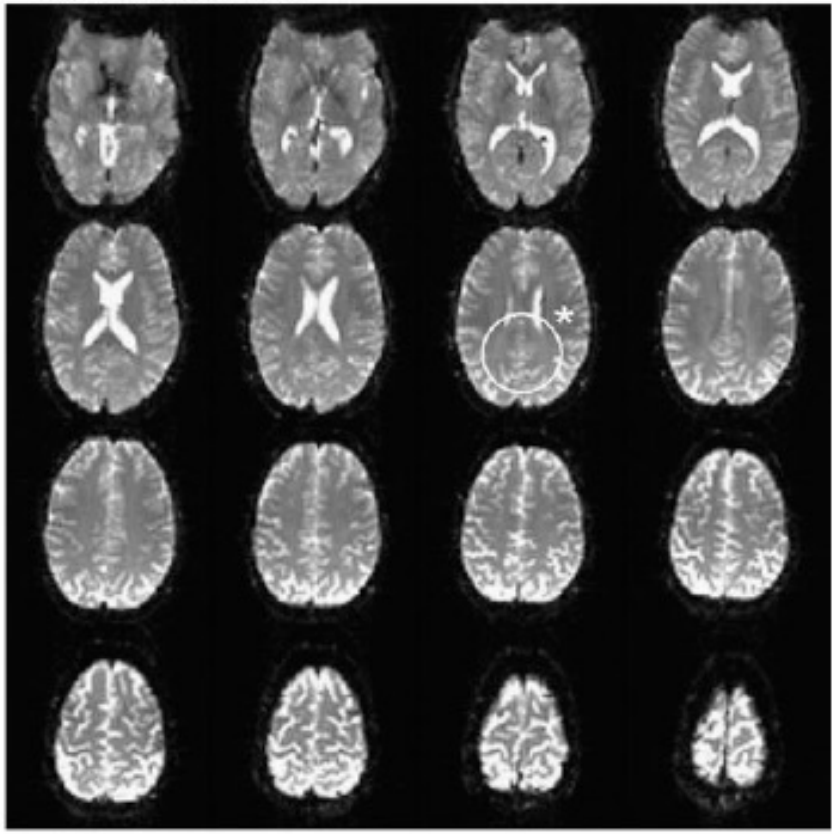

A
EPI sequence schematic (conventional fMRI)
Excitation
ADC
RF
Slice
Read
Phase
0
t(ms)
100
B
EPI sequence schematic (continuous fMRI)
RF
Slice
Read
Phase
0
t(ms)
100
C
Recorded EPI sound
(conventional fMRI)
Sound amplitude
1
0
0
t(s)
1
D
Recorded EPI sound
(continuous fMRI)
0
t(s)
1
E
Power spectrum of
recorded conventional
EPI sound
Power (au)
12
8
4
0
E_i
488 - 688 Hz
0
1000
2000
f(Hz)
F
Power spectrum of
recorded continuous
EPI sound
F_i
488 - 688 Hz
0
1000
2000
f(Hz)

Conventional EPI



*Mean SNR, 35

Continuous fMRI



*Mean SNR, 38

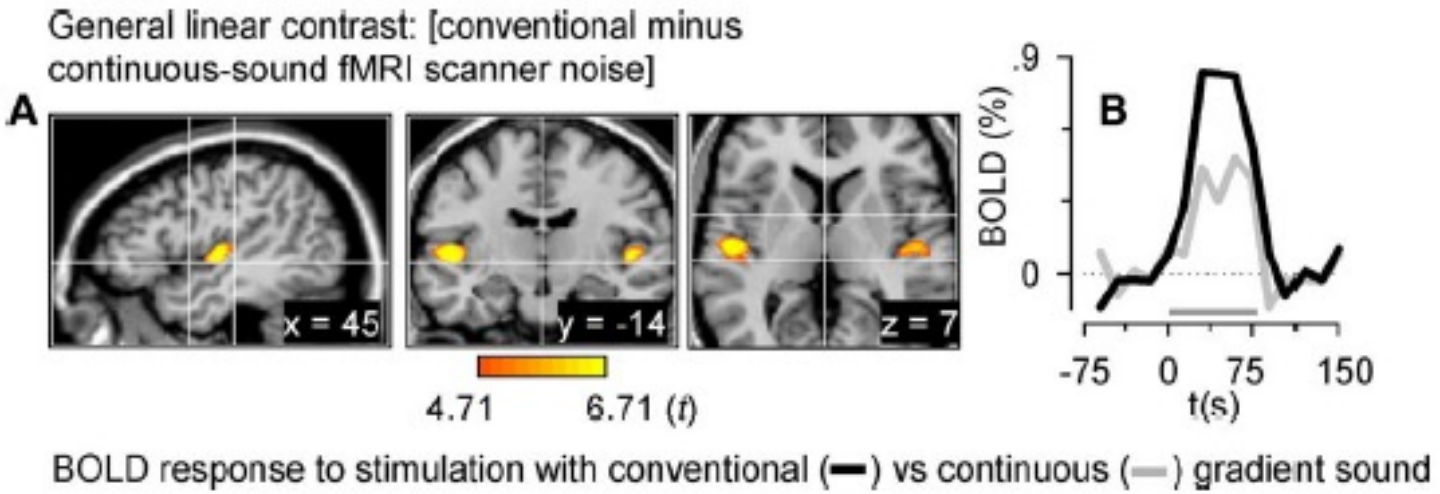


Fig. 3. Differential brain response to gradient noise emitted by conventional vs. continuous-sound fMRI as measured using (silent) sparse imaging in combination with headphone presentation of tape-recorded fMRI sound in 12 subjects (experiment 1). Sparse sampling was characterized by short scans (1.3 s) and long (14 s) silent intervals without scanning (functional slab covered auditory and surrounding temporal cortex). The activation map (A) represents the group general linear contrast between responses to stimulation with conventional vs. continuous-sound fMRI gradient noise ($P_{corrected} \leq 0.05$). (B) Signal time-course averaged across all subjects in auditory cortex shown in panel A (black line, BOLD response to stimulation with conventional fMRI sound; gray line, BOLD response to stimulation with continuous-sound fMRI gradient noise). This demonstrates that the baseline BOLD signal level associated with continuous-sound fMRI is lower than the baseline level during conventional fMRI.

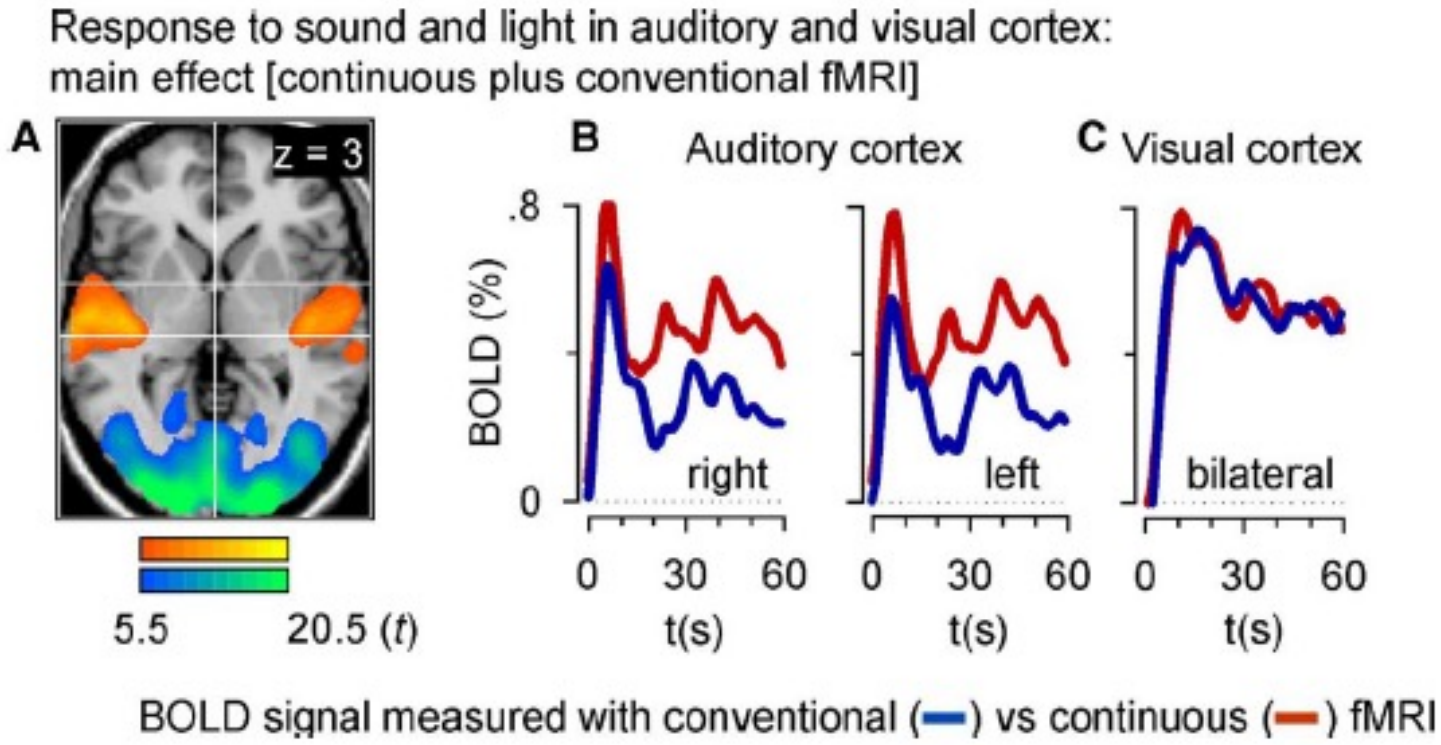


Fig. 4. (A) Main effects of response to pulsed sound and light measured with continuous-sound and conventional fMRI ($P_{corrected} \leq 0.001$). Corresponding BOLD signal time-course in auditory (B) and visual (C) cortex (red, measured with continuous-sound fMRI; blue, measured with conventional fMRI). Note, continuous-sound fMRI produced an enhanced BOLD signal only in the auditory but not in the visual system, demonstrating a domain-specific physiological effect.

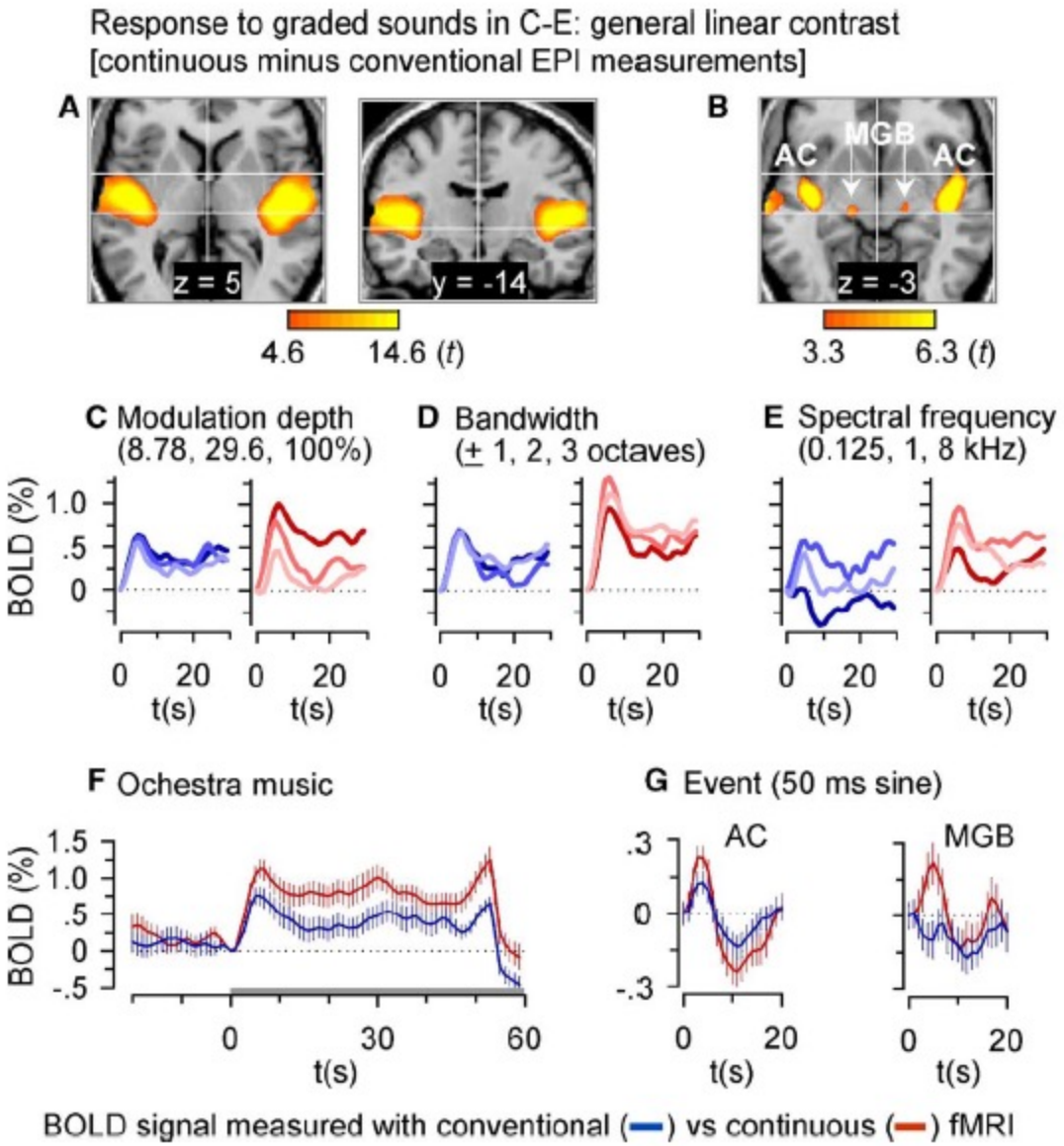


Fig. 5. General linear contrast between response to all graded sound stimuli shown in panels C–E measured with continuous-sound vs. conventional fMRI; (A) auditory cortex ([AC], $P_{corrected} \leq 0.05$) and (B) medial geniculate body ([MGB], $P_{uncorrected} \leq 0.001$). (C–E) The BOLD signal time-courses (red, measured with continuous-sound fMRI; blue, measured with conventional fMRI) are derived from auditory cortex (A), increasing color depths in plots represent increasing stimulus grades (experiments 3–5). (F) BOLD response in auditory cortex (A) to orchestra music (experiment 6; note, the gray bar represents the 60 s during which music was presented, the BOLD signal decrease at the end was not related to the end of stimulation but to a change in the musical properties); (G) BOLD response in auditory cortex (A) and medial geniculate body (B) to sine tone lasting 50 ms (experiment 7). Data in panels F and G are mean ± standard error.

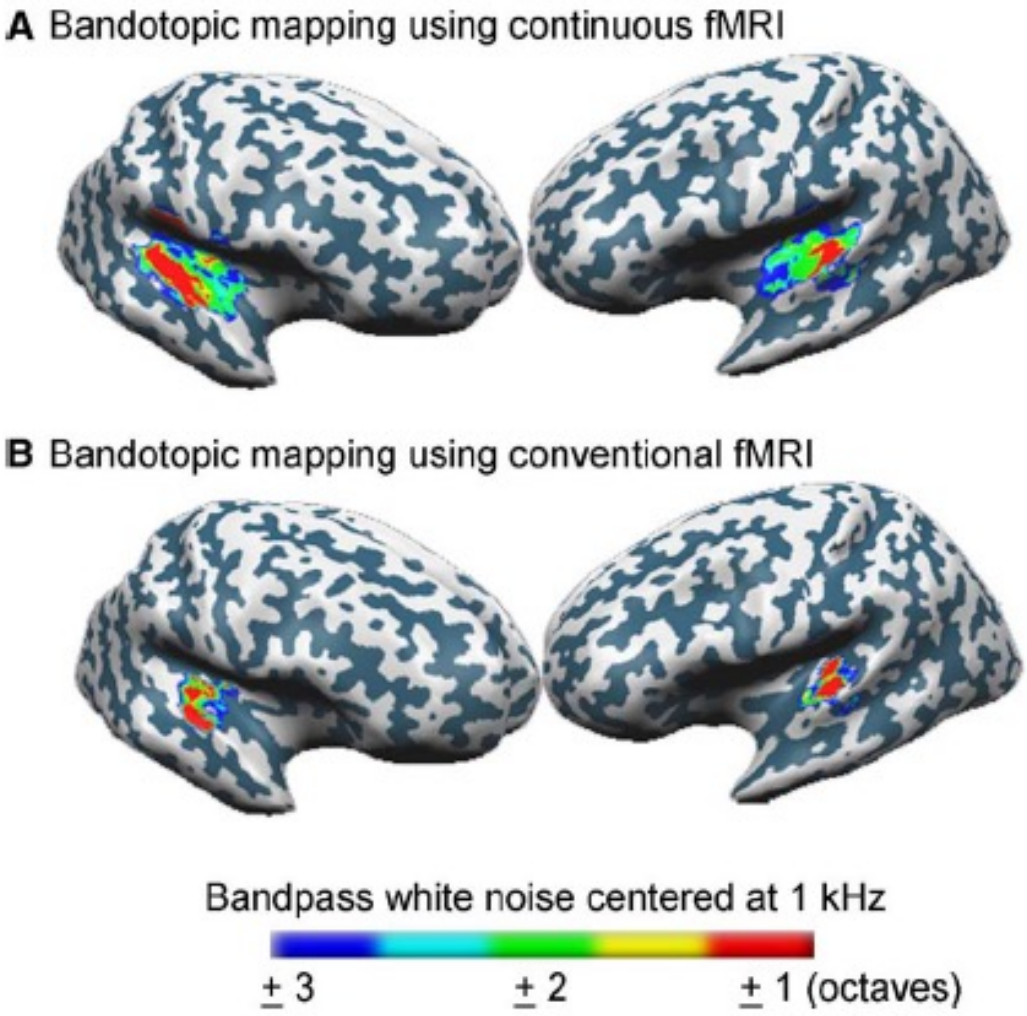


Fig. 6. Group representation of bandpass white noise with centrifugal activity pattern in the auditory cortex (experiment 4), as measured with continuous-sound (A) and conventional (B) fMRI. The central core regions of auditory cortex prefer narrow band noise, while belt regions prefer broad band noise. The BOLD signal time-courses are given in Fig. 5D.

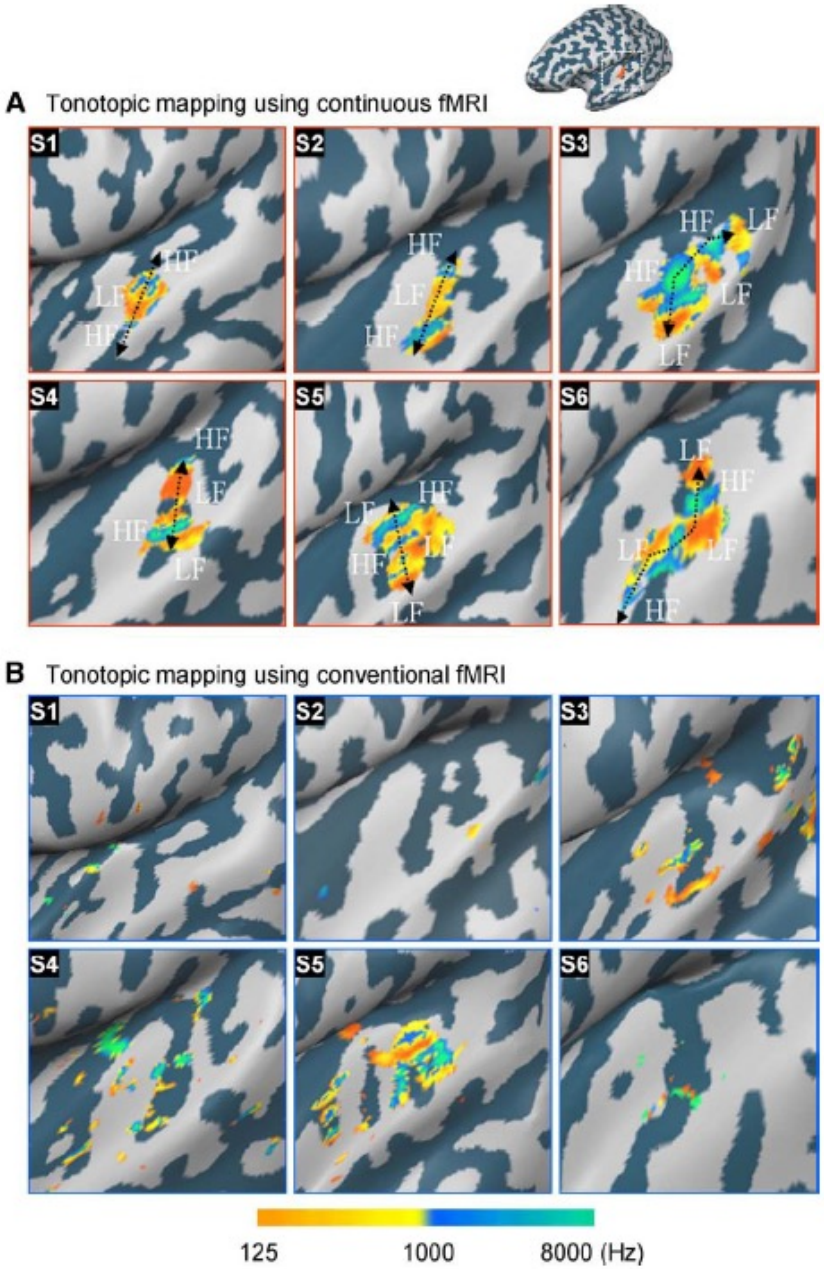


Fig. 7. Individual subject tonotopic mapping in six subjects (S1–6) obtained with continuous-sound and conventional fMRI. (A) Individual subjects' representation of three sound frequencies (experiment 5) suggesting the presence of tonotopic mirror-symmetric maps in the auditory cortex. (B) Same individual tonotopic maps obtained with conventional fMRI measurements at the same statistical threshold as in panel A. The BOLD signal time-courses are given in Fig. 5E.