MEG and fMRI localization of infrasonic and low-frequency sound

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Target Audience Neuroscientists, audiologists

Purpose To investigate how the transition from 'audible' to 'non-audible' sound frequencies (infrasound) is represented in the human brain.

Methods Extensive auditory calibration following ISO 16832:2006 was performed on 15 healthy volunteers to determine subject specific levels of equally perceived loudness. Sinusoidal stimuli of 7 different frequencies from 8 to 250 Hz with ramped lead-in and lead-out (Tab.1) were used for auditory stimulation in fMRI and MEG experiments. A plastic tube of 10 m length guided the tone from a subwoofer through the filter plate to an ear plug applied to the subject's right ear. An optical microphone in a side branch ~20 cm upstream the subject monitored the sound pressure and enabled to check that no higher harmonics were generated. For fMRI acquisition an absorber ear plug for the left ear and earmuffs were fitted. MEG signals were recorded in a magnetically shielded room by a 128-channel gradiometer system (Yokogawa Electric Corp). Afterwards the fMRI was carried out on a 3T scanner (Siemens Verio) with the cryo pump turned off. A discontinuous EPI sequence was used with no gradient activity during the stimulus. The different frequency stimuli plus a silent baseline condition were presented in random order with a total measurement time of 45 min. fMRI data was analyzed using SPM8 [1]; for MEG a non-linear-fitting algorithm [2] was used to determine strength, direction, and position of two magnetic dipole generators of the cortical response to each of the 7 stimuli.

Results The MEG M100 response field maps are shown in Fig. 1 for two subjects representing strong (left) or weak (right) responder groups. The time courses show the signal of a strong channel averaged over all events of a given frequency for the strong responder. For $f \geq 20$ Hz the slope corrected onset time and amplitude change only a little reflecting the constant perceived loudness of the stimulus. At lower frequencies the M100 is difficult to identify. The stronger dipole is located in the region of the contralateral auditory cortex, a weaker on the right hand side. No further dipole was found.

The fMRI results are shown in Fig. 2, indicating a robust, bilateral activation in the auditory cortex which, again, is stronger on the contralateral side. No sensory activation was detected. In contrast to the MEG results the fMRI activation strength depends on frequency (Fig. 3). Around 20 Hz, i.e. at the low-frequency end of the normal hearing range, an activation minimum exists where no statistically significant fMRI signal is found anymore. However at even lower frequencies, 12 Hz and 8 Hz, the signal returns in the fMRI but not in the MEG data.

Discussion Our data support the conventional classification of frequencies into audible and infrasound, above and below ~20 Hz, respectively: both MEG and fMRI signals change significantly at this frequency. But while MEG shows a gradual signal decline when going from 40 to 12 Hz and a complete signal loss at 8 Hz, the fMRI signal in the auditory cortex recovers at very low frequencies. No statistically significant activations in other brain areas are detected. This behavior may be interpreted as a transition from auditory to a different type of activation, e.g. somatosensory [3].

Conclusion A setup was built to present auditory stimuli in an MEG or fMRI environment with equally perceived loudness for frequencies above and below the low-frequency hearing limit (20 Hz). A robust fMRI activation at higher frequencies vanishes at that cut-off but recovers at even lower frequencies down to 8 Hz. This is cautiously interpreted as a hint that different cognitive mechanisms promote 'hearing' above and below the threshold frequency, both of which are located in or near the auditory cortex.

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References [1] Wellcome Department of Cognitive Neurology, London, UK [2] Sarvas J. Phys. Med. Biol. 1987; 32:11-22. [3] J. Foxe, *J Neurophysiol* 88 p.540-543 2002

frequency / Hz	250	125	63	40	20	12	8
duration / s	1.0	1.0	1.0	1.5	2.0	2.5	3.0
SPL / dB_{SPL}	80	94	100	105	116	122	127

Tab. 1 stimuli parameter: Duration is valid for MEG, for fMRI duration was fixed to 3 s. Sound pressure levels SPL are mean values with a standard deviation across subjects of 3.45 dB.

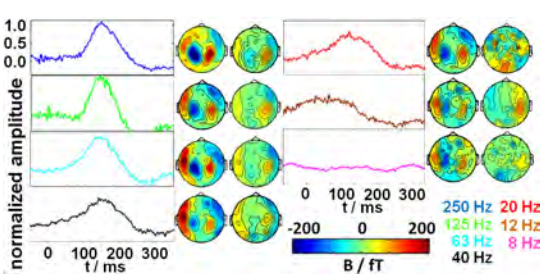

Fig.1 averaged MEG signal and field maps of two subjects, a strong responder left and a weak right.

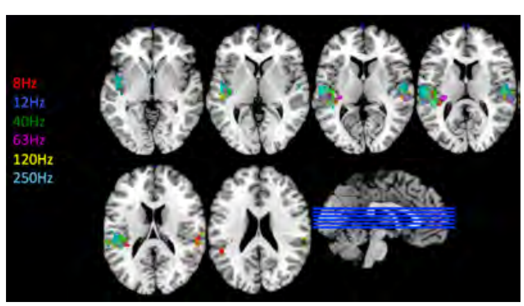

Fig.2 fMRI group activation maps for stimulus against rest; p<0.001, cluster size>22. No significant activation at 20 Hz.

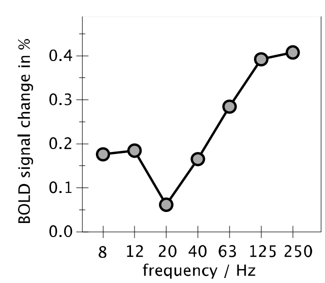

Fig.3 bilateral BOLD response in primary auditory cortex