Functional MRI measured auditory response properties to tone stimuli differing in intensities near and above hearing threshold: Comparison with Magnetoencephalograhy

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INTRODUCTION: The coupling of the hemodynamic BOLD response to underlying neural substrates responsible for sensory and cognitive processes is not entirely understood. This has implications when making neural inferences bases on Functional MRI investigations. For example, the response properties of the evoked neural generators and that of the BOLD response may differ for various parametric stimulus manipulations. Previous fMRI studies have shown an intensity dependence on the auditory BOLD response to simple tone stimuli (1,2). Magnetoencephalography, measures magnetic fields intimately related to neural activity (intra-cellular currents) and can serve as an effective adjunct to fMRI studies. In this study we use MEG to confirm the attenuation effect tones intensity on the hemodynamic response, with the aim to elucidate the response properties (sensitivity) of fMRI to changes in stimulus intensity at and above hearing sensation level (SL).

METHODS: The same subjects were imaged during both silent event-related functional MRI and MEG techniques while 1000 kHz tones were delivered to the right ear at 5 different stimulus intensities above sensation threshold (SL) Intensities were 5, 10, 20, 30, 40 dB SL and were presented in random blocks according to stimulus type. fMRI was performed using a 1.5T Twin Excite MRI (GE MS, Milwaukee, WI) standard gradient echo EPI sequence sensitive to the BOLD effect. The fMRI imaging parameters were: matrix=128x128, FOV=26cm, TR=1s, TE=50ms, number of slices = 8, slice thickness=5mm. 30 stimuli in each stimulus block were presented at 30sec intervals. Images were acquired every 15sec and were offset 5sec with respect to the stimulus onset, This paradigm that effectively produced a (silent) control condition. 'Stimulate' fMRI software (Strupp et al., 1996) was used to perform a pixel-wise students T-test for the stimulus and control conditions and activation maps representing the 96% confidence interval were produced. A 3-pixel clustering requirement also served as additional criteria for 'activated' pixels. The number of pixels (Np) activated in the superior temporal gyrus (STG) were counted and their percent signal increased (%SI) calculated. Extent of activation EoA was defined as the product of Np * %SI (3). Magnetoencephalography was performed on a 151 channel whole head MEG (CTF systems). MEG data were acquired time-locked to stimulus onset with a sampling rate of 1250kHz and low pass filter of 400Hz. Data was further digitally filtered offline from 1.5-40Hz. Trials containing artifacts were removed, and at least 100 trials were averaged to produce the resultant auditory response wave form. The amplitude (M-Amp) measured in femtoTesla (fT) of the M100 response component, arising at about 100ms and known to be related to pre-attentive auditory sensory processes were recorded. The amplitude of the M100 has been related the extent of neural activation (3).

RESULTS: Comparison of the respective measures of neuronal extent for the various stimulus conditions revealed that fMRI EoA at low intensities (5-20dB) is attenuated with respect to higher intensity presentation ($p<.05$,5dB vs 40dB). fMRI EoA differentiation between lower frequencies was not resolvable. MEG Amp was positively related to signal intensity being stronger for higher stimulus intensities. Additionally, MEG responses at lower intensities were differentiable for most comparisons ($p<.05$). On the other hand, MEG Amp at higher intensities became statistically non-distinct. Correlation results of the response properties for fMRI to MEG was favorable ($r=.78$), but correlation became negative when the 40dB condition was omitted. Correlation of the MEG Amp response to the stimulus intensity changes was remarkable ($r=.97$) and was not dependant on any one condition.

CONCLUSION: The results of this study demonstrate an increase in auditory response signal for increased 1000kHz stimulus intensity for both fMRI and MEG measures. MEG was able to resolve neural activation differences to changes in low stimulus intensities whereas fMRI was less clear. The signal response in fMRI and MEG are inherently different due to the temporal resolution difference in each measure. MEG having a temporal resolution on the order of milliseconds is reflective of a neural response at an instantaneous time point and fMRI having a resolution of seconds likely reports a response convolving multiple processes. Whether these technical differences in each method are responsible for the disparity in results between fMRI and MEG in this study is not answerable here. However the observation that there exists a MEG neural response that varies with stimulus intensity at peri-threshold auditory stimulus intensities suggests that the BOLD fMRI response properties in this stimulus intensity range may not reflect the stimulus properties.

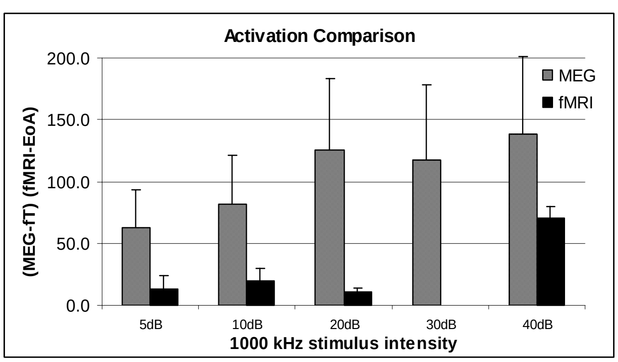

Figure 1.
fMRI and MEG extent of activation measures across subjects for each stimulus condition.

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