Comparison of fMRI Activation Measured with Gradient- and Spin-Echo EPI During Visual Perception

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Synopsis: We compared fMRI activation measured with gradient- and spin-echo based fMRI during visual perception of faces, which is mediated by a distributed cortical network. With both fMRI techniques, bilateral activation was observed in multiple regions, including the inferior occipital gyrus, fusiform gyrus, superior temporal sulcus, amygdala, inferior frontal gyrus, and orbitofrontal cortex. When compared with the gradient-echo sequence, activation measured with the spin-echo sequence was significantly reduced. This decrease was manifested by reduced cluster size, lower statistical significance, smaller amplitude of the fMRI signal, and smaller number of subjects who showed the effect.

Introduction: The vast majority of cognitive fMRI studies have employed gradient-echo (GE) sequences, which are sensitive to both large vessels and small capillaries. Spin-echo (SE) sequences, in contrast, reflect changes in oxygenation in microvessels in the vicinity of the activated tissue, and are less susceptible to signal dropout. The aim of this study was to compare between GE- and SE-based fMRI during visual perception of faces. We hypothesized that with SE-EPI regions prone to static dephasing effects would exhibit improved functional signal.

Methods: *Stimuli and Paradigm:* Thirteen subjects were presented with four different types of face stimuli: black and white line drawings and gray scale photographs of unfamiliar, famous, and emotional faces. Phase scrambled versions of these faces were used as visual baseline. Each stimulus was presented for 3 s. Three alternating epochs of faces (36 s) and scrambled faces (24 s) were included in each run. Five runs (line drawings, famous, emotional and 2 runs with unfamiliar faces) were collected in randomized order.

Data Acquisition: Data were collected using a 3 T Philips Intera whole body MR scanner (Philips Medical Systems, Best, The Netherlands) equipped with a transmit-receive body coil and a commercial eight-element head receiver array (MRI Devices Corporation, Waukesha WI, USA). Functional activation was measured using a GE-EPI (TE = 35 ms, 39 transverse slices) and SE-EPI (TE = 75 ms, 27 transverse slices). Slice geometry and orientation were otherwise the same for both acquisitions. A spatial resolution of 2.3 x 2.3 x 3 mm^3 (acquisition matrix 96 x 96) was obtained using Sensitivity Encoding (SENSE [1]) with an acceleration factor of 2.0. Other functional imaging parameters were FOV = 220 mm, TR = 3 s and $\theta = 82°$. A high-resolution 3D T1-weighted scan provided detailed anatomical information for the region of interest analysis.

Postprocessing and Statistical Analysis: Data were analyzed using the SPM2 software [www.fil.ion.ucl.ac.uk/spm/]. All volumes were realigned, corrected for motion artefacts, mean-adjusted by proportional scaling, and smoothed using a 5 mm full-width-at-half-maximum Gaussian kernel. The time series were high-pass filtered to eliminate low-frequency components (filter width 128 s) and adjusted for systematic differences across trials. Clusters were selected that showed significant response to faces as compared with scrambled faces ($P < 0.001$, uncorrected) with 4 or more contiguous voxels.

Results and Discussion: *Image Quality and Susceptibility Effects:* We found that the MRI signal in orbitofrontal cortex and in the vicinity of the inner ear canals was substantially refocused in the SE-EPI images, while GE-EPI images suffered from severe signal loss in these regions (Figure 1). Such signal dropout was caused by phase coherence loss in static field inhomogeneities, and was therefore considerably reduced by the 180° refocusing pulse of the SE sequence.

Activation within a Network of Face-Responsive Regions: We found activation in response to faces within multiple, bilateral regions [2] with both GE and SE contrasts. Attentive viewing of faces, as compared with scrambled faces, evoked significant responses in the inferior occipital gyrus (IOG), fusiform gyrus (FG), superior temporal sulcus (STS), amygdala (AMG), inferior frontal gyrus (IFG), and orbitofrontal cortex (OFC). Although we found bilateral activation within these regions, the spatial extent of the activation was larger in the right hemisphere (GE-EPI $p < 0.001$, SE-EPI $p < 0.01$).

Gradient- versus Spin-Echo based fMRI: Both cluster size and t-values (Figure 2) were significantly smaller in the SE-EPI data as compared with the GE-EPI data ($p < 0.0001$ and $p < 0.0001$, respectively). This finding is consistent with intrinsic differences in the functional contrast underlying SE- as compared to GE-based fMRI [3].

Differential Responses to Various Face Formats: To compare the differential activation evoked by all face stimuli as measured with the GE- and SE-EPI sequences, we performed a conjunction analysis. In most subjects, the common regions activated by both techniques were the IOG, FG, and the STS. Within these regions we found smaller amplitudes of the fMRI signal with the SE-EPI ($p < 0.001$). Regardless of the fMRI sequence, famous and emotional faces evoked stronger responses than unfamiliar faces (GE-EPI $p < 0.001$, SE-EPI $p < 0.01$), consistent with previous reports of valence enhancement [4].

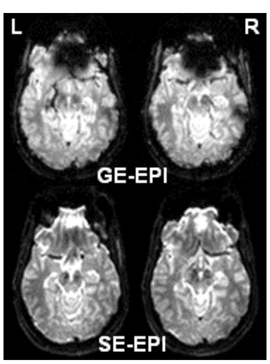

Figure 1: Two transverse slices taken from the GE- and SE-EPI functional time series of one subject. While GE-EPI images show severe signal dropout in susceptibility affected regions, such as the OFC, the MRI signal is refocused in the SE-EPI images.

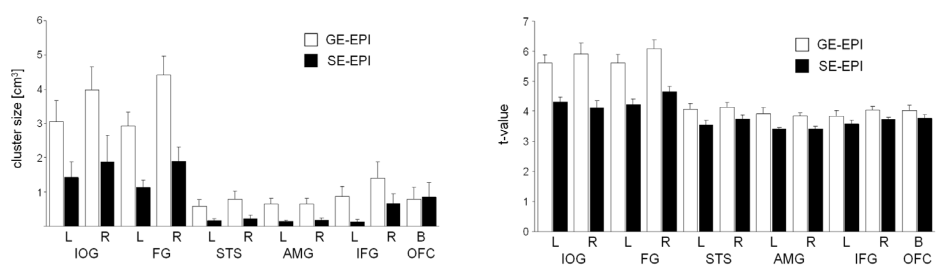

Figure 2: Response to faces: Comparison of cluster size (left) and t-values (right) in GE- and SE-EPI data. Error bars indicate SEM. L = left, R = right, B = bilateral.

In summary, our data indicate that activation within the same multiple, bilateral regions can be measured with both GE and SE contrasts. This activation, however, was significantly reduced in the SE data. Additionally, although the MR signal was refocused in susceptibility affected regions such as the OFC, and contrary to our hypothesis, an improvement of the functional signal was not observed. It therefore seems that using SE-based fMRI in cognitive studies should be reconsidered.

References:

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