Multi-Sequence Comparison of Temporal lobe fMRI Activation at 4.0 T

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Introduction: Over the past fifteen years, functional MRI has been used to investigate cognitive brain function. High-field fMRI offers additional benefits such as increased contrast-to-noise, with sequences having been developed to compensate for distortion effects due to increased susceptibility field gradients (SFGs). Using such sequences, it becomes possible to gain insight into brain regions affected by SFGs. However, most groups have a preferred protocol for collecting fMRI data that can vary considerably between sites, and for the most part, these techniques have not been extensively compared. With few exceptions (e.g. Li et al. [1]), most new techniques have only been compared to one 'standard' sequence like EPI, spiral-out, or spiral-in/out [2]. Furthermore, testing is often done using non-cognitive tasks (i.e. breath-hold, visual or motor tasks) or with external SFG sources (i.e. doped samples as opposed to sinus-induced SFGs). It can also be difficult to draw conclusions about different sequences across different studies due to varying parameters and/or field strengths. The current study involved a comprehensive evaluation of commonly-used techniques like EPI and spiral-out, as well as techniques designed to recover signal in SFG regions using BOLD methods (spiral-in [2], spiral-in/out, spiral-in/in [1] and ASE spiral [3]) and non-BOLD methods (FAIR [4] and spin-echo spiral-in/out) at 4.0 T. A cognitive task that has been used in the pre-surgical evaluation of temporal lobe epilepsy patients [5] was used to elicit activation in the inferior temporal lobe (as well as other brain regions). Notably, this work allowed us to examine the differing effects that the contrast and signal recovery mechanisms have on fMRI activation in both SFG and non-SFG regions.

Methods: All data were acquired using a 4T Varian INOVA whole body MRI system. Gradients were provided by a body coil (Tesla Engineering, UK) driven by 950 V amplifiers (PCI) with a maximum of 35.5 mT/m at 120 T/m/s. The RF coil was a quadrature TEM head coil (Bioengineering Inc) driven by a 7kW RF amp (AMT). Spiral waveforms were calculated using the method of Salustri et al. [6] and images were interpolated using the input spiral waveforms (no measured trajectories) as well as field map and navigator correction.

All six of the sequences were run for all subjects with the parameters matched as closely as possible given the differing contrast mechanisms. All sequences had 5-mm axial slices, gap = 0.5-mm, 64x64 (24x24 cm^2), volume TR = 3 s, 2-shot (FAIR was 1-shot). Spiral-in/out and spiral-in/in used TE = 25 ms and acquired 26 slices. EPI used TE = 25 ms and acquired 24 slices. ASE spiral used TE = 61 ms, TE* = 25 ms and acquired 14 slices. Spin-echo spiral-in/out used TE = 61 ms and acquired 17 slices. FAIR used TE = 3 ms, TI = 1400 ms, gap = 2-mm and acquired 8 slices.

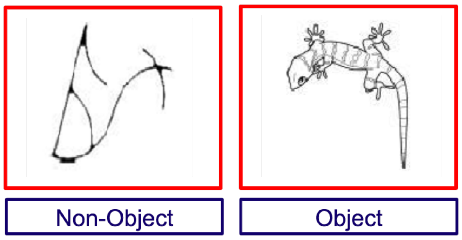

Figure 1: Sample cognitive stimuli used to elicit activation in the temporal lobe. Subjects indicated whether the image was an object or non-object.

Six healthy participants completed an object discrimination task to elicit temporal lobe activation. The task required participants to distinguish real objects from non objects (Figure 1). The task consisted of 5 active blocks (36 s each) and 5 rest blocks (18 s each). A unique version of the task was used during the testing of each sequence (line drawings did repeat between tasks, while object stimuli did not). All sequences and tasks were counterbalanced. To reduce habituation, the response button used to indicate the presence of an object alternated across tasks.

Images from multiple acquisition sequences were summed using a straight average. Activation maps were calculated using a model convolved with the standard gamma hemodynamic response function in FSL [7]. Cluster threshold was used such that $p<0.05$. In order to determine the maximum intensity and extent of activation measured in the temporal lobes for each sequence z-score statistics were calculated using FEATQuery [7].

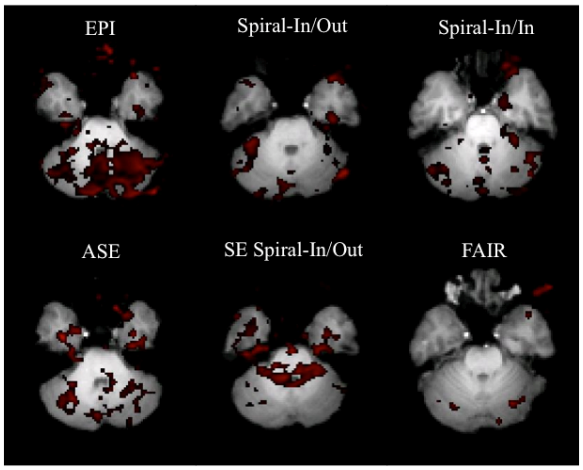

Figure 2: Sample activation maps in the inferior temporal lobe overlaid on the subject's anatomical. Activation scores thresholded at $z > 1.5$.

Results: Sample activation maps for representative subjects from all six sequences can be found in Figure 2. Each sequence detected some extent of fMRI activation in the temporal lobes using a cognitive object discrimination task. A graph of the average maximum z-score in the temporal lobe for each sequence can be viewed in Figure 3. The dual spiral sequences, ASE spiral and SE spiral-in/out were most successful at detecting temporal lobe activation with higher activation scores and larger activation extents. FAIR has the smallest z-scores, while there is no significant difference between spiral-in/out, spiral-in/in, ASE spiral and EPI (although it does appear to have consistently lower activation scores than the other spiral sequences). It should be noted that the preliminary analyses thus far use temporal lobe ROIs encompassing the entire temporal lobe, which includes both SFG and non-SFG regions. In addition to the temporal lobes, activation was also detected in several other brain regions, including visual areas, primary motor areas, and cerebellar regions.

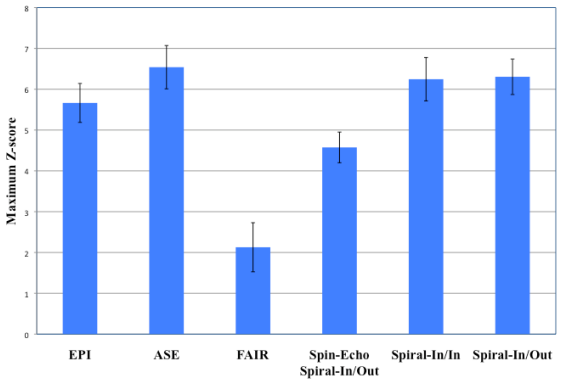

Figure 3: Maximum z-scores in a temporal lobe ROI for six different sequences (averaged across six subjects).

Discussion & Conclusions: This study allows the evaluation of six fMRI sequences during a cognitive task optimized to elicit activation in the temporal lobes. The preliminary analyses show significant differences in the intensity and extent of activation between different techniques. However, further analyses at the group level will allow for a more robust examination of the effects that varying contrast mechanisms may have on the extent and strength of activation in SFG regions. These analyses will also allow us to localize temporal lobe activation at the group level and determine whether this activation is being displaced in SFG regions when using fMRI techniques whose performance may be affected by field offsets. Further analyses will also be done to examine the activation patterns of individual images (i.e. spiral-out and spiral-in images obtained from spiral-in/out acquisitions). Ultimately, this novel study will provide a thorough comparison of fMRI sequences, which may guide sequence decisions for future protocols and enhance the interpretation of activation results viewed in brain regions affected by SFGs.

References: **[1]** T.Z. Li *et al. Magn. Reson. Med.* **55**, 325-334 (2006). **[2]** G.H. Glover & C.S. Law. *Magn Reson. Med*. **46** 515-522 (2001). **[3]** KD Brewer *et al. NMR in Biomed.* **22** 654-662 (2009). **[4]** S.-G. Kim & N.V. Tsekos. *Magn Reson. Med* **37** 425-435 (1997) **[5]** Gawryluk et al. *17th Annual ISMRM* E-Poster #3371 (2009). **[6]** C. Salustri *et al. J. Magn Reson*. **140** 347-350 (1999). **[7]** S.M. Smith *et al. NeuroImage* **23** 208-219 (2004).