# SENSITIVITY AND SPECIFICITY OF MHASTE BOLD FMRI ON MT/V5 ACTIVATION

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## Introduction

Recently, a novel BOLD fMRI method based on a modified half Fourier single shot TSE technique, namely mHASTE, has been developed and proven to yield significant BOLD activations on visual cortex in response to flashing checkerboards [1,2]. Also with high SNR and artifact-free images, mHASTE is potential for high resolution BOLD fMRI [3]. However, the neuronal activities induced by the flashing checkerboard are massive, involving a great extent of the visual cortex and vessels of all sizes within. Such paradigm brings up the issue in differentiation of macro- and micro-vascular contributions to BOLD signals. Although mHASTE is considered to be more specific to BOLD signals from microvasculature [1,2], it may be sensitive to $T_2$ changes in large veins as well. It is hard to demonstrate the functional specificity of mHASTE if the observed BOLD signals of different origins are spatially mixed. Attempts have been made to demonstrate the sensitivity of SE-EPI, which is also spin echo based method, to detect high level cognitive activities in regions affected by strong susceptibility artifacts using the Stroop task [4]. However, a direct comparison was not plausible as the results of GE-EPI at those areas were not available due to signal dropouts [4]. The purpose of this study is to use a classic fMRI paradigm, i.e. MT/V5 activation [5], which only activates a small but well defined region of the visual cortex, to demonstrate 1) the ability of mHASTE in detecting BOLD response of medium level neuronal activities, and 2) the improved functional specificity of mHASTE over EPI based sequences.

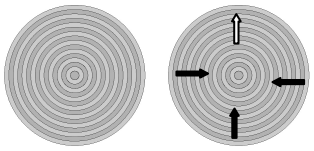

**Fig.1** a) Control condition: stationary ring cycles pattern. b) Activation condition: ring cycles repeatedly expand (white arrows) and contract (dark arrows). Contrast between adjacent rings is 15%

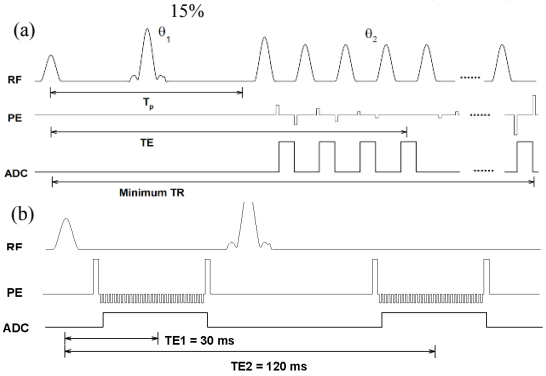


**Fig.2** a) mHASTE diagram. $T_p$ was introduced to enhance dynamic averaging. $\theta_1$ and $\theta_2$ were 180° refocusing pulses. b) double contrast EPI sequence for simultaneous GE/SE acquisition.

## Methods

The visual stimuli consisted of concentric rings of ~2 cycles per visual angle degree with 15% contrast. During the control condition, the concentric rings were stationary (Fig.1a) for 24s, while during the activation the rings alternated between expansion and contraction every 4s for 24s (Fig.1b). The motion of the expanding/contracting rings is known to selectively activate the V5 area of visual cortex (also known as middle temporal area, MT) [5], whose primary function is motion detection. Five healthy volunteers with written consent participated in this study. All data were acquired on a Siemens Verio 3T system (Siemens Medical Solutions, Erlangen, Germany) with product 12-channel head coil. mHASTE sequence as described in previous work [1] was used (Fig.2a), with scanning parameters as: TR/TE=2000/82ms, FOV=220mm, Tp=50ms, bandwidth = 360Hz/pixel, 3x GRAPPA and 8 slices (5mm thick) approximately centering at the MT/V5 area. For comparison, a double echo EPI sequence (Fig.2b) was used to collect both GE- and SE-EPI data in a single acquisition. The protocol parameters were similar to mHASTE's, except that the TEs of the GE and SE echoes were 30 and 120ms respectively, bandwidth was 1563Hz/pixel, and GRAPPA was 2x accelerated. For all data sets, 64x64 data were acquired. The scanning order of sequences was pseudo randomized for each subject to remove any systematic trends. All images were processed using SPM8, xjview and in-house Matlab programs. Functional results were then spatially normalized to an ICBM-defined T1 standard space, followed by single-subject analysis for individual activation. A common ROI for each data set was then determined by thresholding the combined contrast maps of all 5 subjects, and finally the signal change (ΔS) and t-values were extracted voxel-wise from all subjects using these ROIs.

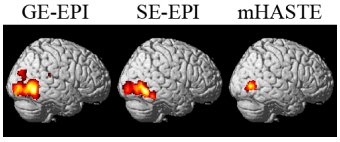


**Fig.3** Combined activation contrast maps determined by a common threshold. The mHASTE cluster is exactly where MT area is located [6].

## Results

Significant activations on MT/V5 area were obtained with all three data sets. The thresholded, combined contrast maps are shown in Fig. 3, showing a significant yet well constrained activation for mHASTE. The talairach coordinates of the mHASTE cluster (peak at x=50.0, y=-67.5, z=0.9) highly matches the MT/V5 location reported in literatures [4, 6]. The extracted ΔS and t-value from all subjects are displayed in Fig.4 in terms of normalized ΔS distribution and scatter plots of ΔS vs. t-value. ΔS of mHASTE, SE- and GE-EPI are 0.33±0.23%, 0.43±0.43% and 0.40±0.31%, respectively.

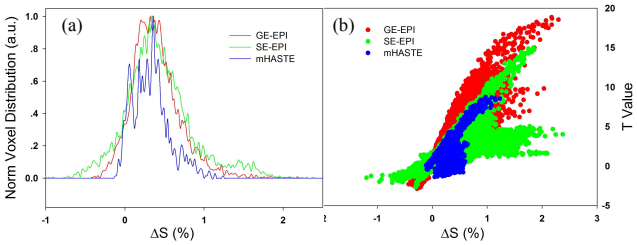


**Fig.4** a) Normalized distribution of ΔS. b) Voxel-wise scatter plot of ΔS vs. t-value. The data shown include all ROI-extracted voxels from all 5 subjects

## Discussion

In contrast to the flashing checkerboard pattern which extensively activates the whole visual cortex, the MT/V5 paradigm selectively activates a well specified region located within the extent of one sulcus [6]. Such highly localized neuronal activity induced by motion stimuli will 1) induce a milder BOLD signal change due to the much smaller number of activated neurons, and 2) provide a better spatial differentiation between macro- and micro-vascular signals because there are only outgoing but no incoming veins carrying BOLD signal in such a small region. We can see from the results that mHASTE can reliably detect the MT/V5 activation (Fig. 3) with comparable ΔS to EPIs. In general, mHASTE has lower ΔS and t-value than EPI methods (Fig. 4b). However, ΔS of mHASTE is more uniformly distributed (Fig. 4a), suggesting the origin of mHASTE BOLD signal is more uniform (i.e. mainly microvasculature). A look into Fig. 4b will further confirm this conclusion, where voxels of low t-value but high ΔS were seen in GE- and SE-EPI but not mHASTE. Such voxels as indicated in Fig. 3, would be those peripheral voxels in the activation cluster (note the lack of such voxels in mHASTE), indicating sensitivity to draining vein signals for EPI but not for mHASTE. Furthermore, compared to previous works using flashing checkerboard paradigm, where ΔS was 1.10±0.08%, 1.38±0.10% and 2.04±0.12% for mHASTE, SE- and GE-EPI respectively [1], mHASTE yielded a much less reduction in ΔS than EPIs did in this MT/V5 study (see Results), also suggesting the reduction of draining veins effects has less effect on mHASTE. In light of above evidences, mHASTE proves to be mainly sensitive to microvasculature and thus has improved functional specificity over EPI methods. Interestingly, both GE- and SE-EPI data contained voxels with negative ΔS, while mHASTE had few such voxels, further analysis is needed to determine whether this is due to the difference in BOLD signal sources or just the different ROI sizes we selected. In conclusion, we have demonstrated that mHASTE is sensitive to medium level BOLD signals induced by the MT/V5 activation patterns, and with such highly localized activations, the improved functional specificity of mHASTE were demonstrated and better appreciated than EPI sequences.

**Reference** [1] Y. Ye, et al. Neuroimage, 2009;49(1):457-66 [2] Poser, et al. Magma, 2007;20(1):11-7 [3] Y. Ye, et al. ISMRM Stockholm 2010:5071
[4] Norris, et al. Neuroimage, 2002;15(3):719-26 [5] Tootell RB, et al. Nature 1995;375:139-141 [6] Dumoulin, et al. Cereb Cortex. 2000;10(5):454-63