Activation extent and tissue specificity of high-TSNR BOLD at 7T

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PURPOSE. In a recent study [1], we demonstrated that with optimal TSNR and using a sufficiently versatile response model it is possible to detect wide spread activations all over the brain in response to a relatively simple visual stimulation plus attention control task using a 3T scanner and 3.75x3.75x3.8mm^3 voxels. The purpose here is to extend that work to help better understand the tissue specificity of the responses. In particular, we focus on: (1) contribution of partial volume effects (PVE) to statistically significant responses in grey matter (GM) and white matter (WM); (2) the effect of removing the attention control part of the task on the activation maps; and (3) how scanning at higher field strength (with a smaller BOLD point spread function (BPSF) and lower contribution from draining veins) affect results. The main differences between the two studies are: field strength (3T vs. 7T), voxel size (53.44 vs. 8mm^3) and cognitive load (presence/absence of control task).
METHODS. *Exp. Protocol:* Fixate on a centered crosshair for the duration of each run. Each run had 5 repetitions of 20s of left hemifield stimulation followed by 40s of rest. *Data Acquisition:* 65 functional scans (GRE-EPI, TR=2s, 54Slices, 2x2x2mm^3) were acquired in one subject on a 7T scanner (6 visits). *Pre-processing:* phys. noise removal, slice time and head motion correction, inter-run registration, removal of motion and 1st derivative fluctuations, intensity normalization. *Quality Metrics:* TSNR, contrast-to-noise (CNR) & spatial smoothing were computed for each separate run. *Statistical Analysis*: In a manner similar to [1] we computed statistical maps of activation (p_{FDR}<0.05) and percentage of active volume using 3 response models (sustained only (SUS), onset+sustained+offset (OSO), unconstrained (UNC)) and increasing number of runs (N_{run}) ranging from 1 to 65.
RESULTS. Differences in voxel size and noise profiles resulted in individual 3T scans having TSNR 3.33 times greater than 7T scans. CNR is also 1.52 times greater in 3T data. Additionally, estimated spatial smoothing is 2.41 times greater in the 3T data. These differences, combined with the lower cognitive load for the new task (see Table 1), resulted in activation volumes several times smaller (see ratios in Table 2) at 7T, as compared to 3T, data for all three models. Nevertheless, in agreement with [1], larger N_{run} and/or more versatile models resulted in significant increases in activation extent (Fig 1) and detection of activation sites with diverse hemodynamic response shapes (positively & negatively sustained as well as transient responses) in many occipital, but also subcortical, frontal, parietal and temporal regions. Moreover, 7T activations for larger N_{run}, are constrained to the GM compartment in contrast to 3T data (Fig. 2).
CONCLUSION. These results confirm the previous finding that under optimal TSNR conditions and with versatile enough models activation extends beyond areas commonly reported for simple visual stimulation. Nevertheless, the percent of active volume is significantly smaller in this second study. This is the result of a combination of factors: lower TSNR & CNR for the 7T data, larger spatial smoothing for the 3T data, smaller BPSF associated with GRE at 7T, and lower cognitive demands. Importantly, in this study active regions remained within GM for the highest N_{run} available, suggesting that these activations are not only statistically, but also biologically significant. We plan to acquire 100 runs in 3 subjects with both the original and new tasks with the small voxels at 7T to help segregate differences due to technical (TSNR, BPSF) or cognitive factors (task).
REFERENCES. [1] Gonzalez-Castillo et al., PNAS, 2012. 109:5487-92. [2] Parkes et al. 2005, MRM 54:1465-72. [3] Shmuel et al. NeuroImage 2007, 35:539-52.

Table 1. Differences in Cognitive/Motor Processing Needs across studies

Visual Stim.	Letter/Number Discrimination	Plan Motor Response	Execute Motor Response
3T Full-field | 7T Hemifield	3T Yes | 7T No	3T Yes | 7T No	3T Yes | 7T No

Table 2. Ratio of metrics of interest between 3T and 7T data

	Voxel Size (mm^3)	WM TSNR	CNR	Spatial Smooth (mm)	BPSF (mm)	% Act. Extent (1run)			% Act. Ext. (65runs)		
						SUS	OSO	UNC	SUS	OSO	UNC
3T	53.43	273	5.61	5.54	3.99 [1]	4.6	10.9	13.7	66.1	84.9	94
7T	8	82	3.69	2.14	2.34[2]	0.5	0.7	0.7	15.3	24.3	28.5
3T/7T	6.68	3.33	1.52	2.59	1.70	8.82	15.33	20.10	4.32	3.49	3.30

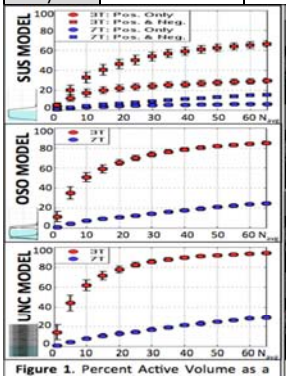

Figure 1. Percent Active Volume as a function on runs (N_{avg}) for p_{FDR}<0.05

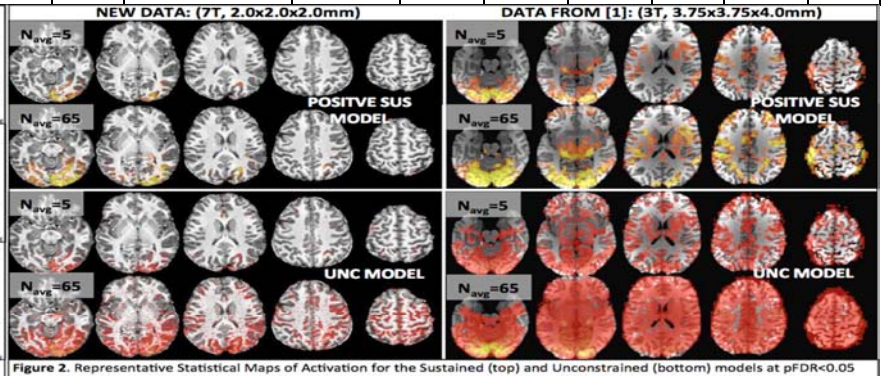

Figure 2. Representative Statistical Maps of Activation for the Sustained (top) and Unconstrained (bottom) models at pFDR<0.05 using 5 or 65 runs. Previous data collected on the 3T is shown on the right and new data collected on the 7T on the left.