fMRI for functional localization and task difficulty assessment during visual search for military vehicles

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Abstract
Past and current U.S. Army computational vision models designed to determine the difficulty of visual detection of camouflage for military vehicles are extremely limited in the sense that they do not encompass much of the brain outside the retina and visual cortex, and within those areas, do so to a very limited degree. A method and preliminary experiments to obtain the raw data to construct better and more representative models of human vision and cognition is presented. The inclusion of specific neurocircuitry in the computational model as opposed to the "black box" standard used in psychophysics is now possible. The combination of psychophysics and fMRI has the potential to give a more complete view of the neural systems that are relied on for different perception tasks related to camouflage and deception.

Introduction

The general purpose and mission of the U.S. Army RDECOM-TARDEC's Visual Perception Laboratory (VPL) is to measure the probability of detection of ground combat vehicles with various camouflage/stealth treatments and how those treatments compare to untreated vehicles. The data collected in the VPL is used to assess the effectiveness of camouflage treatments as well as to validate and improve U.S. Army visual and infrared detection models.[1] Standard photosimulation methods can only proceed so far in model development and assessment. For a deeper understanding of the cortical processes involved in camouflage assessment, a new technology is needed.

Procedures that use Magnetic Resonance Imaging (MRI) to measure the functional localization of neural processes (via changes in blood flow and related hemodynamic parameters) have been widely adopted because of their relative good temporal resolution (100-1000 msec) and ever-increasing spatial resolution The use of MRI in this context is conventionally called "functional Magnetic Resonance Imaging" (fMRI). Many of the early studies concerned the use of fMRI for probing visual perception [2,3] and while subsequent years have shown a growing range of applications, there continues to be a substantial amount of current research applying fMRI-based experiments to questions associated with vision.[4,5] There is, therefore, a large literature of general brain mapping studies concerned with visual perception that forms the foundation for this research. The

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14. ABSTRACT
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authors propose to use this technology for vehicle detection model development and testing as well as for the augmentation of conventional perception lab testing.

Method

Images of cortical activity were taken using a 1.5 T Magnetic Resonance Scanner (General Electric Twin Speed, see Fig. 1) using the echo planar or equivalent option and a typical T2* weighted gradient echo sequence such as (TE=40 ms, TR=2 secs, flip angle = 60 deg). A 40 x 20 cm field of view (FOV) imaged on a 256 x 128 grid yielding an in-plane resolution of 1.56 x 1.56 mm and slice thickness of 5mm and voxel size of (3x3x4.5mm, 20x20 cm FOV, 64 x 64 grid) was used for the present study. Images were acquired on multiple contiguous slices chosen to cover the entire human brain.

Fig. 1: Columbia University fMRI scanner, Courtesy of Dr. Hirsch

Methodology

The proposed procedure for using fMRI for rapid camouflage assessment and search task localization is to present a set of images of military ground vehicles to a subject using a rear projection screen while they are lying prone inside the magnet and have the subject indicate by means of a track ball, the location of the vehicle. The images were shown to subjects while they were being imaged in the same manner that subjects are shown the image in the visual perception lab at TARDEC minus the condition of the subjects being in a prone position. The images were randomized over subjects.

The image sequence used was as follows: first a random dot pattern was shown for two seconds to clear retinal memory, then the stimuli image was shown for ten seconds in which there may or may not be a military vehicle, then a black image was displayed to for eight seconds shut down the visual system. In all cases, the background was the same. The design matrix was seven ranges, one target, three screen locations of the vehicle, and twenty-five percent no-target images.

Below in Fig. 2 is a stimuli image that is part of the data set shown to the pilot test subjects. The target vehicle, which in this test was a 5 ton truck, is in the center of the image. The image set used is part of a TARDEC and Marine test on electro-optical filters for laser protection at 29 Palms in New Mexico.

Fig. 2: 5 Ton truck at 700m

Data Analysis

During the presentation of the test imagery, response data was accumulated for standard signal detection type of analysis for comparison to the fMRI data as shown in Fig.'s 3, 4 and 5 below.

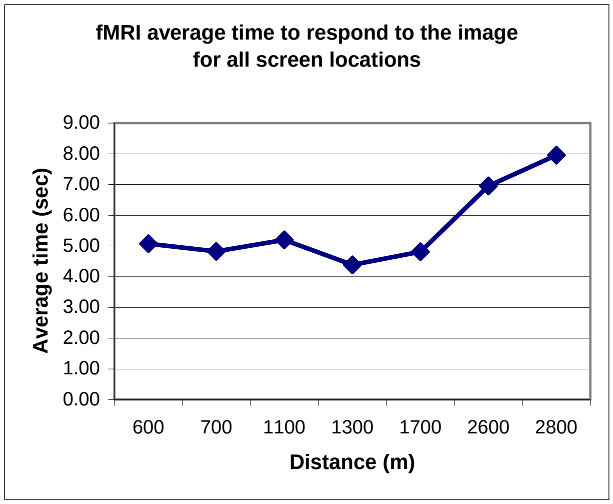


Fig. 3: Average search time for the truck at each range

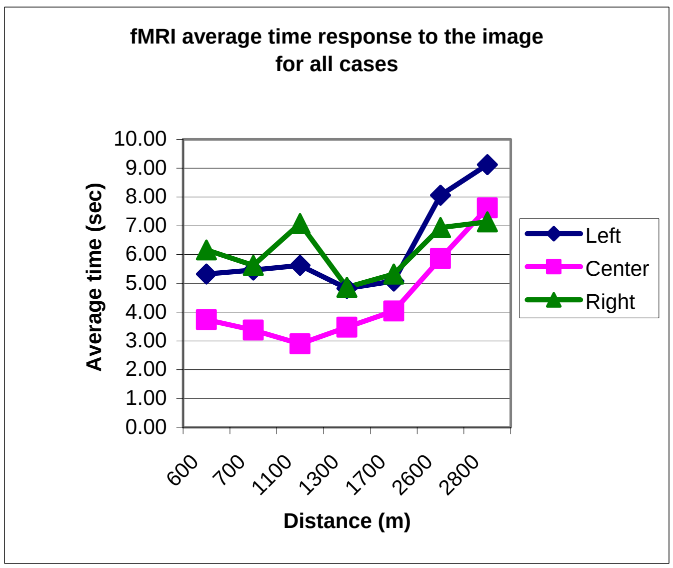


Fig. 4: Average search times for the truck at each range and screen position

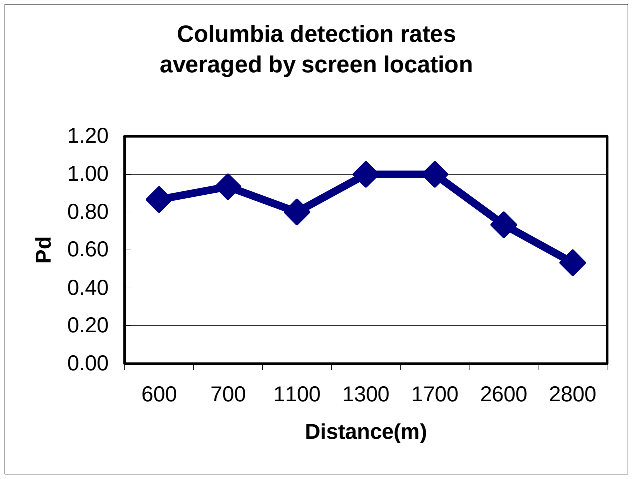


Fig. 5: Average detection probabilities for each image

Figures 6 through 12 below are the results of the Statistical Parametric Mapping (SPM) of the fMRI data for one of the subjects. The data indicate the large amount of neural activity associated with searching for targets. The SPM program is run using MATLAB.[6]

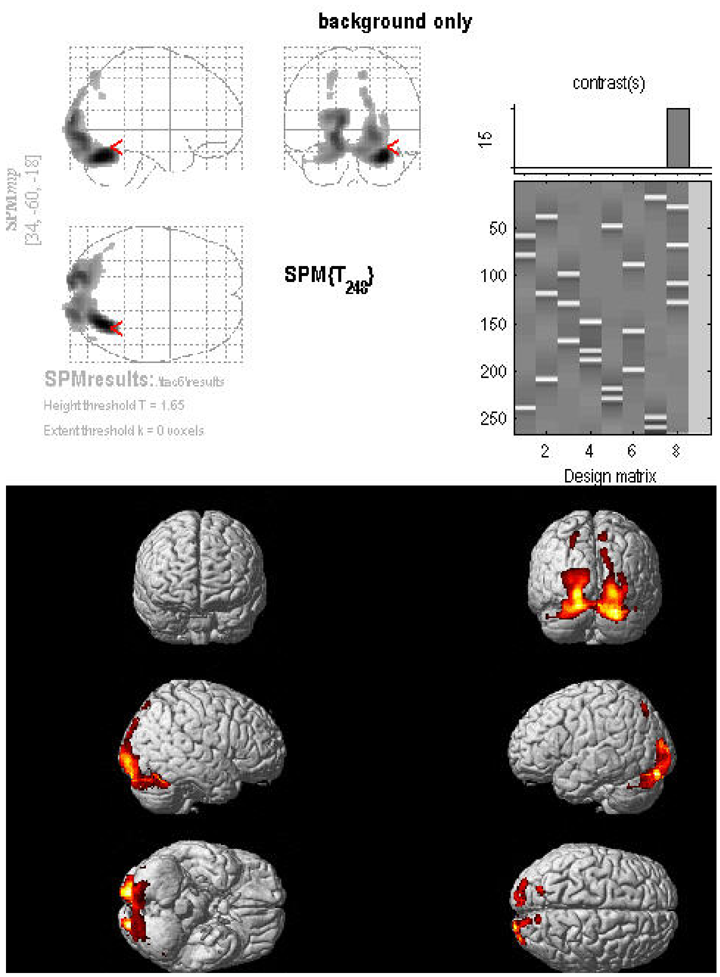


Fig. 6: No-target image SPM results

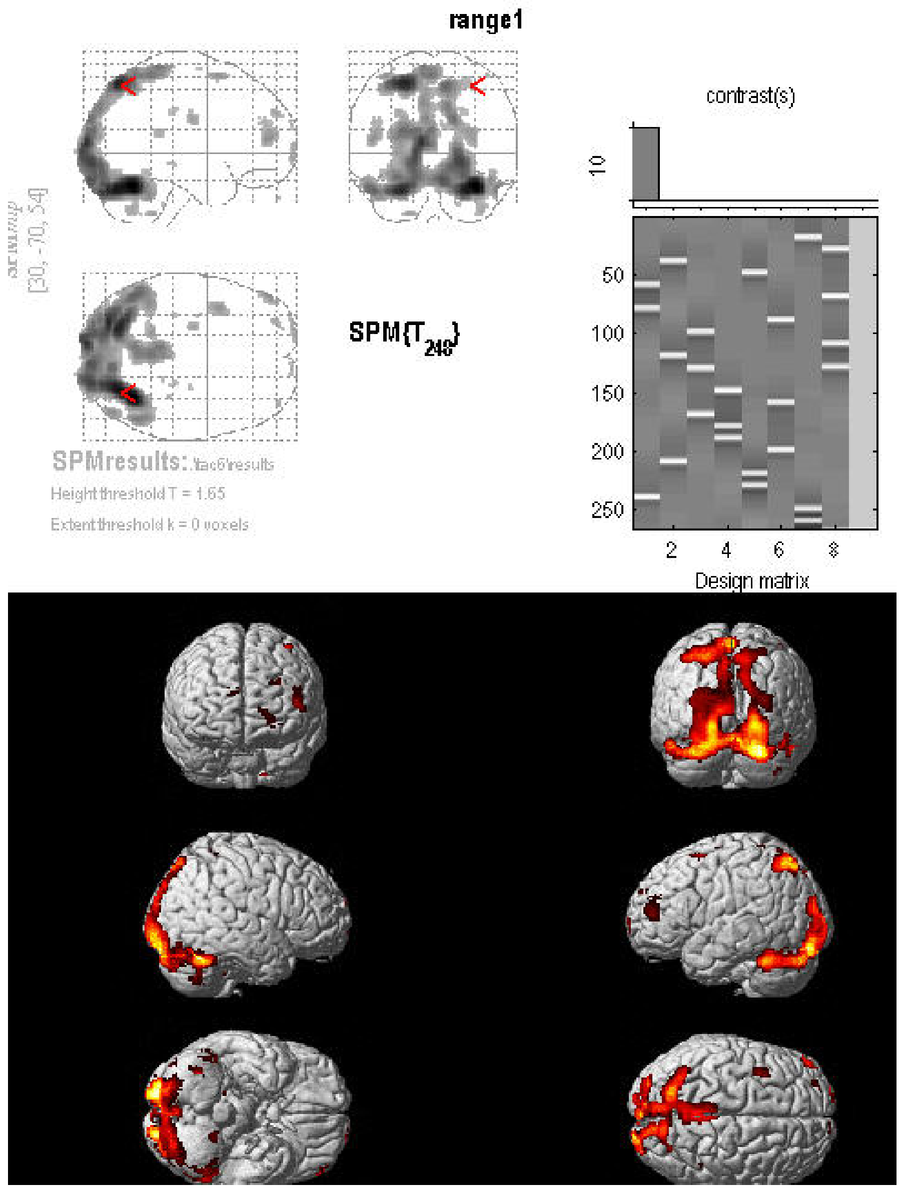


Fig. 7: Range 1 SPM results

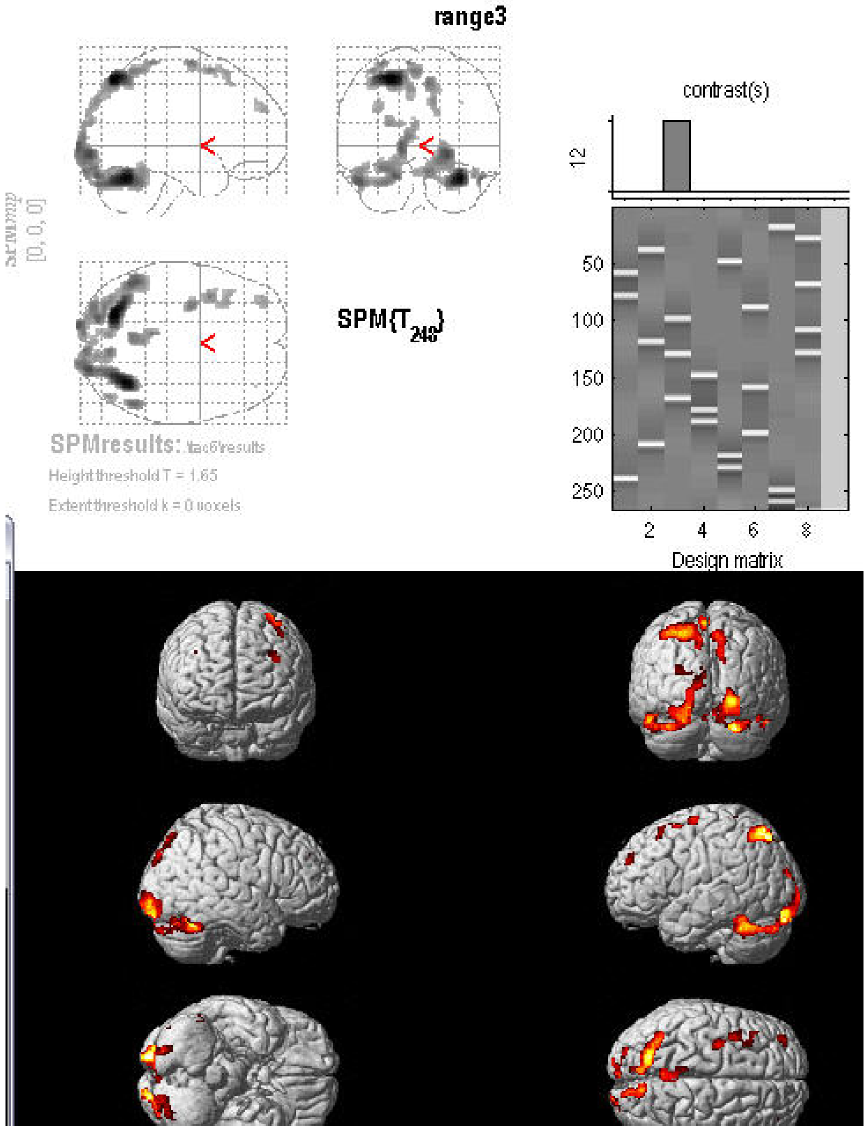


Fig. 8: Range 3 SPM results

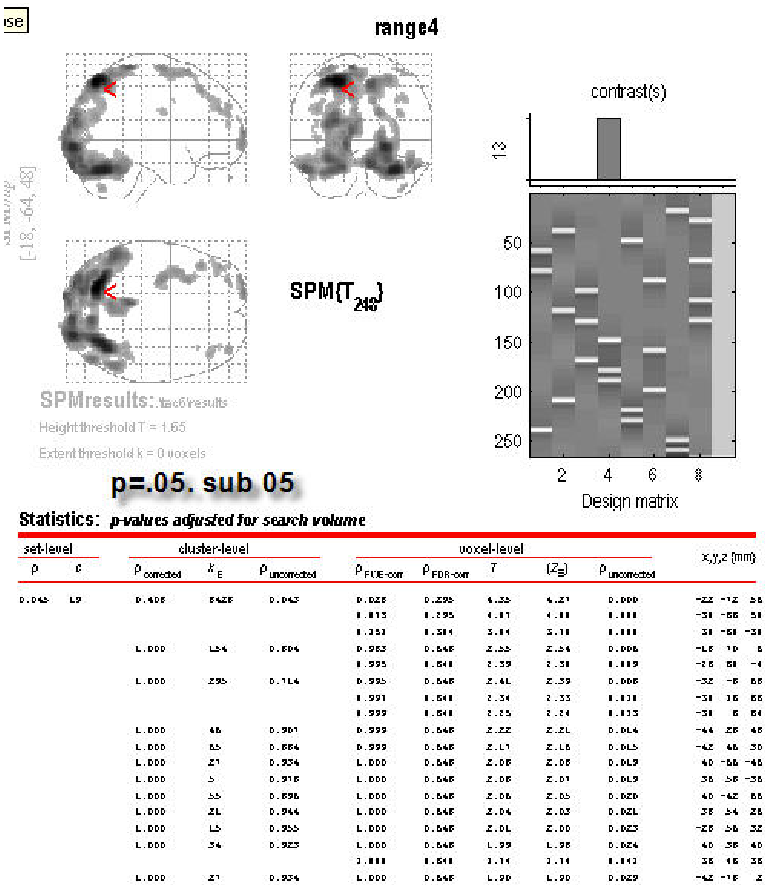


Fig. 9: Range 4 SPM results

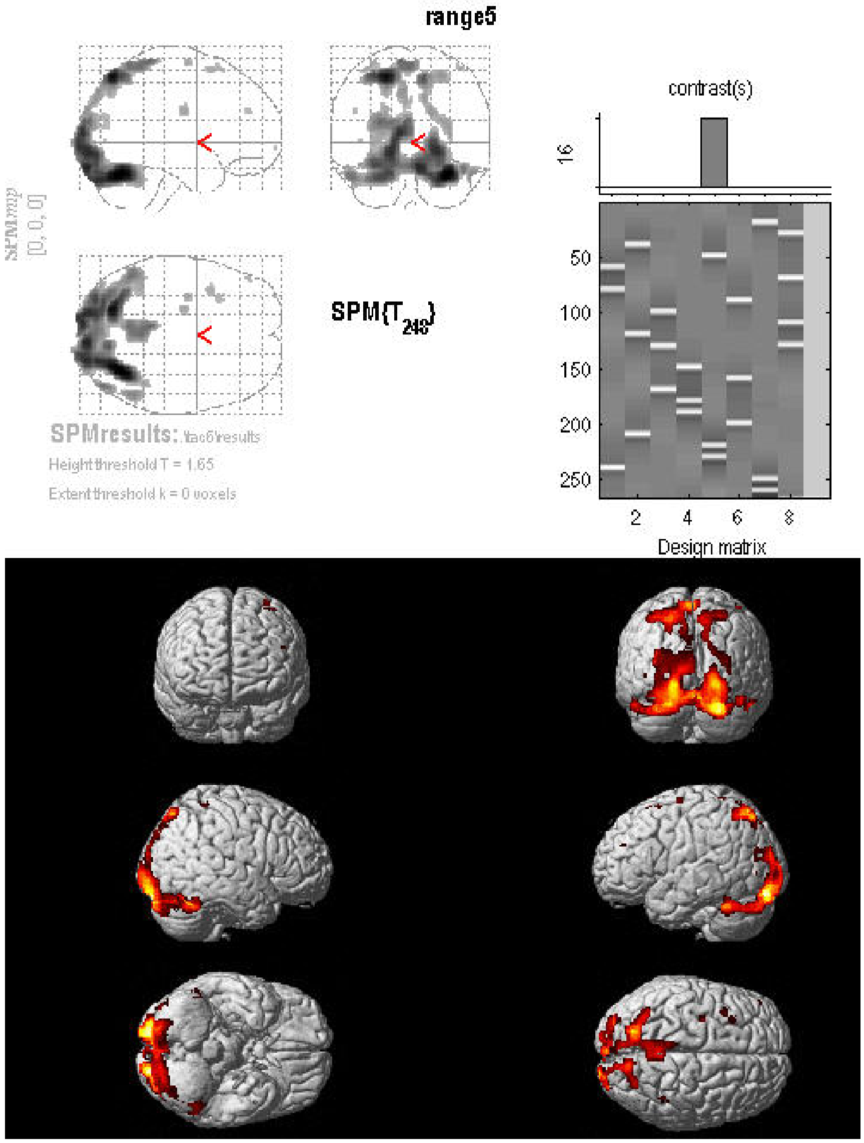
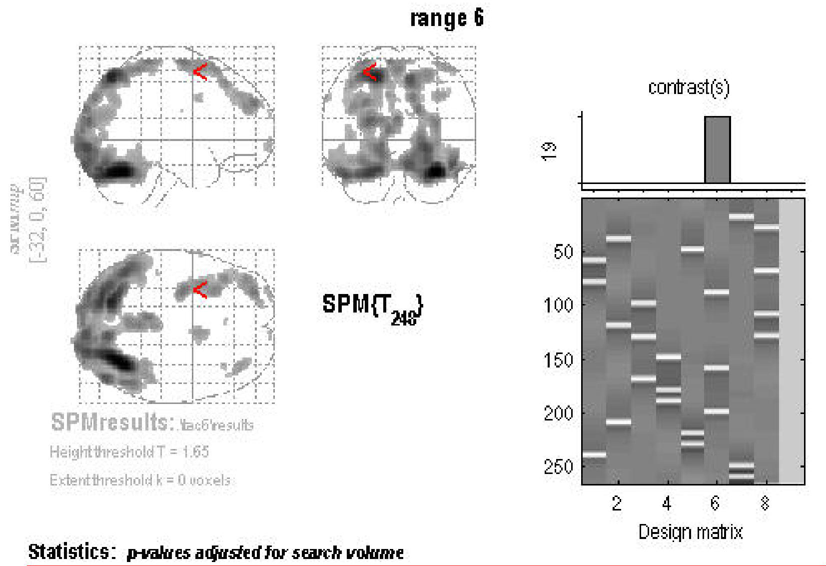


Fig. 10: Range 5 SPM results



Statistics: ***p-values adjusted for search volume***

cluster-level			voxel-level					x,y,z {mm}		
$p_{corrected}$	k_E	$p_{uncorrected}$	$p_{FWE-corr}$	$p_{FDR-corr}$	T	$(Z_\equiv)$	$p_{uncorrected}$			
0.998	815	0.498	0.891	0.324	2.85	2.82	0.002	-30	-8	10
			0.931	0.339	2.80	2.78	0.003	-30	54	32
			0.916	0.433	2.60	2.58	0.005	-32	20	62
			0.911	0.431	2.59	2.57	0.005	-30	0	64
			0.982	0.432	2.56	2.54	0.006	-42	20	50
			0.987	0.458	2.52	2.50	0.006	-40	46	30
			0.999	0.516	2.26	2.25	0.012	-30	44	36
			1.000	0.644	1.97	1.96	0.025	-30	60	32
			1.000	0.644	1.86	1.86	0.031	-44	30	36
			1.000	0.644	1.86	1.86	0.032	-42	36	50

table shows 32 local maxima more than 4.0mm apart

Fig. 11: Range 6 SPM results

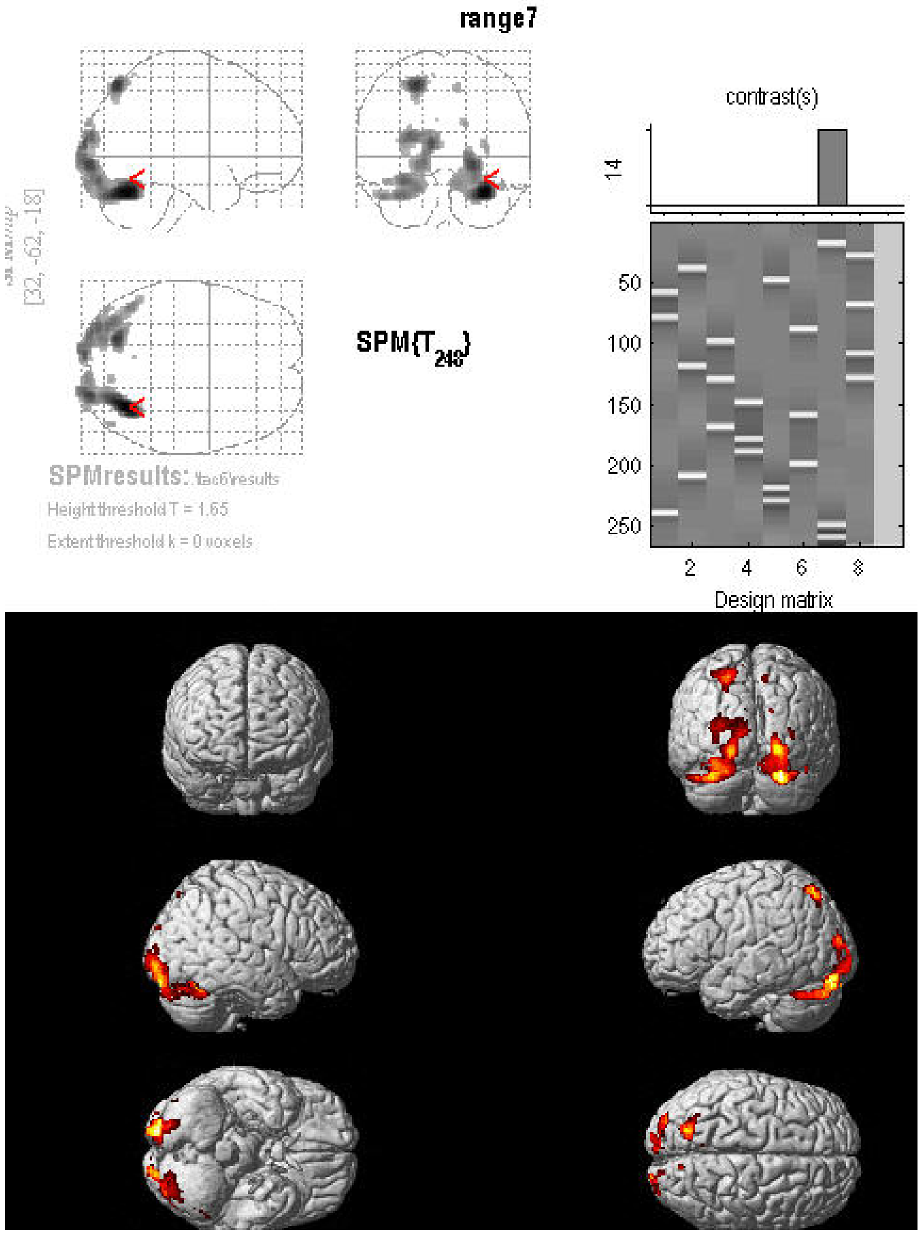


Fig. 12: Range 7 SPM results

Conclusions

The fMRI maps indicate that there is a substantial amount of cortical processing occurring during visual search. Active areas include functional areas associated with early and late vision, language formation, and memory. The data show clear activation of the early and ventral visual areas, LO, and parietal regions. Computational models therefore need to include these areas of the brain to more accurately represent the human visual detection process. Most importantly, the activities in these areas can now be measured, as is indicated by the tables accompanying some of the figures, and used for visual search and detection model development and testing.

Current and future work lies in the area of assimilating the data obtainable from the fMRI maps in to a computer model that encompasses all of the active areas of the brain revealed by the fMRI maps.

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