Reduced Spurious Activation by Continued Controlled Attention in fMRI Measurements of Primary Sensory Areas

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INTRODUCTION

Studies in macaque monkeys have shown that sustained attention can reduce fMRI noise by reducing the influence of unattended stimuli [1,2]. Human electrophysiological studies have provided evidence that attention can increase sensory gain [3], and neuroimaging studies have shown attentional modulation of neural activity in many visual areas. The goal of this study was to control the subjects' attention during the fMRI experiment, especially for studies of primary sensory areas, and to measure and compare the influence of controlled attention on the activation.

MATERIALS AND METHODS

Four volunteers (ages 28-42; male) participated in the experiment. Imaging was conducted on a 3T system (Siemens Magnetom Trio). High-resolution anatomic images were obtained for each participant. Functional images were collected with standard EPI measurement (TR 3000ms, TE 30ms, matrix 64*64, 34 axial slices including all visual areas, isotropic resolution of 3mm) with retrospective motion and distortion correction. Two functional scans were performed for every subject, each run with 80 repetitions in a block design (circular checker board; 30s off, 30s on). The participant viewed the display through an angled mirror attached to the head coil. The main task was to look at the fixation point in the center. In one condition, the subjects were instructed to press a button when the color of the fixation point changed from red to green (transiently for 200ms). The changes occurred in random intervals between 5 and 10s throughout activation and baseline and required continued attention to the fixation point. In the second condition, only the red fixation point without any changes was displayed. All data sets were processed with SPM5. After smoothing with a 4mm Gaussian kernel voxel exceeding a statistical threshold of $p<0.001$ (FWE) were considered to be activated. Based on anatomic knowledge of the visual system, the activation within the occipital lobe and on the optic pathway (including LGN) were considered truly positive. The number of activated voxel within the optical areas as well as the number of false positive (e.g. voxel in the frontal lobe) was determined for each experiment. In order to detect the stimulus-correlated motion, the covariance between the realignment parameters and the paradigm was calculated.

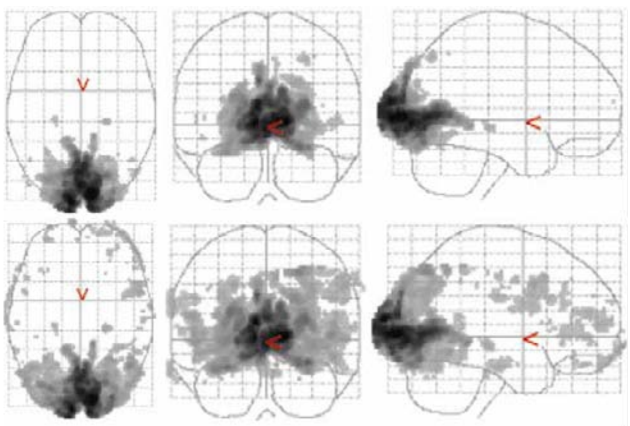

Fig.1: The first row of images were the task with transient attention of green fixation point, more concentrated activations were presented within the visual areas. The second row of images were the state with unchangeable red fixation point and more activation appeared outside the visual areas.

RESULTS

The activations for the two conditions were highly reproducible between subjects. Representative maps are shown in Figure 1. The results of the quantitative evaluation are shown in Table 1. All four subjects showed significantly less false positive activation in areas not involved in visual processing during the task with controlled continued attention. During continued attention the size of the truly activated areas in the visual cortex is smaller compared to the task without continued attention. No significant difference in the stimulus-correlated motion was detected

Table 1. Quantitative evaluation of the number of activated voxel

	without attention to fixation		with continued attention	
	false positive	anatomic based	false positive	anatomic based
Sub 1	976	13895	183	11732
Sub 2	928	13247	9	8802
Sub 3	327	6678	20	5671
Sub 4	747	12087	328	9676

$P < 0.001$, FWE corrected, Voxel > 0.
Anatomic based: voxel within occipital lobe and visual pathway (LGN).
False positive: the activated voxel outside the visual areas.

DISCUSSION

1) This study demonstrates that continued and controlled attention reduces the number of spurious activations outside the known visual cortex area. These activations are mainly in the frontoparietal and temporoparietal cortex. This is most likely due to a better controlled reference state during which the subjects do not shift their attention unpredictably causing activations that are not intentionally task-intended. Task-related motion may also cause such activations. However, in our experiments this did not contribute significantly. 2) The activation within the visual areas is reduced for the task with controlled continued attention. This result is similar to previous studies, where the activation due to visual input decreased with increasing cognitive load [1,2]. In addition, attention can increases the specificity of the neural population representing the attended object [4]. Transient attention has been show to increase stimulus-evoked activity in early visual area [5]. In our experiment, the visual activation size was smaller during continued controlled attention. We conclude that the activation is caused solely by the changes of the visual input and not due to unwanted attentional modulation of activation, which is known to change the activation via a top-down regulation. Therefore, studies of primary sensory areas should control for the subjects' attention even during the reference condition. However, the cognitive load of the attention task should be kept low to minimize possible confounding interactions between the attention controlling task and the primary task of interest.

REFRENCES

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