

fMRI Of Visual Perception: Networks Identified By SPM And Independent Component Analysis

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Introduction

The Motor-Free Visual Perception Test-revised [1] was adapted to a functional MRI (fMRI) environment to provide a measure of the neural activation involved in such a task. Two complementary methods, one applying the general linear model and the other a data driven approach, Independent Component Analysis (ICA), were utilized to analyze the fMRI data. Both methods yielded similar, but not identical, results and detected a network of robustly activated visual, parietal, and frontal areas as well as thalamus and cerebellum. Additionally, the ICA method segregated functional elements into separate maps and identified a fronto-parietal component. The results suggest that the cerebellum may play a significant role in visual perceptual processes and that the parietal signal decreases during this visual task.

Methods

Six right-handed healthy, screened volunteer subjects, participated in the study. All subjects had good visual acuity. Subjects provided informed consent and the protocol was approved by the Johns Hopkins Institutional Review Board.

Fifteen MVPT-R figures (approximately half the test battery) were presented an average of 15s apart using the computer program E-Prime. A white asterisk on a black background was visible during the inter-stimulus intervals. For each item, a central test stimulus was presented above four other figures (one target and three distracters). The subjects looked into a mirror to see a screen that subtended 25 degrees of visual field and indicated his/her item choice by pressing a fiber-optically monitored button panel. All figures remained on the screen until a choice was made (an average of 3.60 seconds). A timeline of the experimental paradigm is presented in Figure 1a.

Scans were acquired on a Philips NT 1.5 Tesla scanner. Functional scans consisted of an EPI scan (TR=1s, TE=39ms, field of view=24cm, matrix=64 x 64, st=5mm, gap=0.5mm) obtained consistently over a 5-minute period for a total of 300 scans. Ten scans were acquired at the beginning to allow for longitudinal equilibrium, after which the paradigm was automatically triggered to start by the scanner.

The images were corrected for timing differences between the slices[2,3]. Next the data were imported into SPM99, motion corrected, spatially smoothed(6x6x10mm), and normalized into a Talarach template[4-5].

Data from all subjects were entered into a general linear model framework. "Events" were comprised of the times when the subjects were presented the figure convolved with an estimate of the hemodynamic response function. Data were high-pass (drift removal) filtered by entering sinusoidal functions into the model up to a frequency of 1/30s as covariates and low-pass filtered by smoothing the data temporally with a 4s Gaussian kernel. The resultant statistics were height-corrected for multiple comparisons to $p < 0.05$. Individual analyses were also performed to verify that the trends seen in the group analysis were also seen in each individual subject.

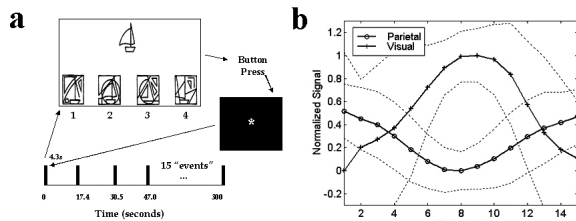


Figure 1: (a)fMRI Paradigm & (b)Averaged parietal and visual (de)activations

Independent component analysis (ICA) is a method that attempts to separate linearly mixed spatially or temporally independent components[6-8]. The smoothed data from each subject were arranged into a 2D matrix of space and time and entered into a spatial ICA analysis. Twenty components were estimated for each subject after

reducing the data via principle component analysis (PCA). The component maps were analyzed manually for spatial structure and those that demonstrated a high degree of spatial structure were grouped, normalized, and averaged. Each resultant group image was then thresholded at a Z-score equal to 2.5 and overlaid onto an EPI image.

Results

The SPM group analysis (Figure 2a) revealed that a number of regions were activated in visual and visual association areas as well as frontal eye field areas/dorsolateral prefrontal cortex (FEF/DLPFC) and the supplemental motor area (SMA). Notably, there was parietal deactivation and extensive cerebellar and visual activation (Figure 1b). A second model was built using the response times, however this did not provide significantly different results.

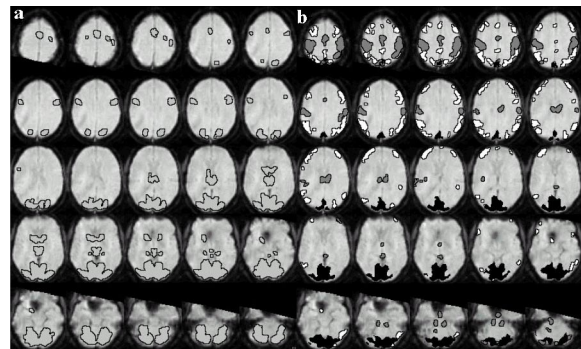


Figure 2: (a)SPM and (b)ICA results

The ICA group results are depicted in Figure 2b. Note that primary motor and SMA (gray), visual (black), and fronto-parietal (white) regions separated into different components. Many of the regional locations identified in the ICA analysis corresponded well with the SPM99 analysis (parietal deactivations are not shown, but agreed well with the ICA results).

Discussion

We have shown that the MVPT-R fMRI paradigm activates a robust network of areas including primary visual, visual association, frontal, parietal, and cerebellar regions and these areas are detected using different and complementary methods: a linear modeling approach via SPM and a data-driven approach, Independent Component Analysis. Additionally, the frontal and parietal regions were grouped by ICA into the same component, suggesting that these areas activate complementarily. Signal in parietal regions decreased following figural presentation whereas signal in frontal regions increased. Finally, cerebellar activation was more extensive than expected, suggesting a significant cerebellar role in the MVPT-R task.

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