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Research Report

Task-related laterality effects in the lateral occipital complex

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ARTICLE INFO

Article history:
Accepted 9 October 2006
Available online 4 December 2006

Keywords:
fMRI
Fusiform cortex
Object naming
Semantic
Task demand
Lateralization

ABSTRACT

Using functional imaging, we investigated the effects of two different tasks on activation in the lateral occipital complex (LOC). Alternating blocks of intact and scrambled objects were presented. In one task, subjects responded when an object repeated (matching task). In a second task subjects silently named objects (naming task). Identical objects (tools, animals and letters) were presented for both tasks. A relative measure of the number of voxels activated in LOC in left and right hemispheres was calculated for each task across a range of thresholds. Also the effects of task demands on category specific areas in LOC were examined. The object matching task resulted in proportionally more activity in the right hemisphere. The object naming task resulted in proportionally more activity in the left hemisphere, most prominently in the anterior portion of LOC. Effectively, changing the task changed the lateralization of activation to intact objects in LOC. In contrast, changing the task did not change the lateralization of category-specific activations. The results suggest that there are task-related top-down influences on the activation of neural populations in LOC as a whole, but the lateralization of category-specific regions in LOC is independent of task demands and may reflect bottom-up processing.

1. Introduction

There is evidence to suggest that neural activations in the ventral visual cortex are modulated by top-down influences. For example, the influence of attention on the activation of neurons throughout the visual cortical hierarchy has been widely researched in both humans and primates (Hillyard et al., 1998; Kastner and Ungerleider, 2000; Treue, 2001; Morrone et al., 2002; Treue, 2003; Murray and Wojciulik, 2004). Less well-known are the top-down effects of task demands on the neural populations in the ventral visual cortex. Given that objects contain a wealth of visual information and task performance may only require processing a subset of this information, it is possible that different tasks recruit different neural populations. In this study, we compared activation patterns in the lateral occipital complex (LOC), an object sensitive region in the occipital cortex, in response to a picture matching and a picture naming task. Given that language processing in most right handed people is specialized to the left hemisphere, we wanted to find out whether hemispheric asymmetries would occur in LOC depending on whether one task recruited language processes more heavily than the other. We also examined the influence of task demands on activations produced to specific categories of objects.

Naming an object requires the integration of perceptual, semantic and phonological processes and activates a network of interconnected cortical regions including bilateral occipital,

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doi:10.1016/j.brainres.2006.10.023

temporal, left inferior temporal, left inferior frontal, left precentral, left basal ganglia, left premotor, and anterior cingulate cortices and left insula cortices (Damasio et al., 1996; Martin et al., 1996; Chao et al., 1999; Moore and Price, 1999b,a; Okada et al., 2000; van Turennout et al., 2000, 2003). A common finding in these studies is the preponderance of activation throughout the left hemisphere in response to object naming. A recent PET study by Price et al. (2005) identified those regions involved in perceptual, semantic and phonological processes of object naming. As expected, processes associated with name production generated activation mostly in the left hemisphere. Semantic and perceptual processes generated mainly bilateral activation.

LOC is involved in the perceptual processing of objects. It has been argued that LOCs role in object recognition is of a general purpose shape analyzer and is not involved in representing conceptual information about objects (Grill-Spector et al., 2001; Tyler et al., 2004). In support of this argument, Malach et al. (1995) did not find any difference in activation to familiar compared to unfamiliar objects in LOC (see also Kanwisher et al., 1996). However, there is evidence that the left fusiform gyrus (portions of the fusiform gyrus lie within LOC) is responsive to semantic manipulations (Simons et al., 2003) and responds more strongly to meaningful objects compared to nonsense objects (Zelkowicz et al., 1998; Gerlach et al., 2002; Vuilleumier et al., 2002).

More recently, Tyler et al. (2004) investigated basic level naming (e.g. naming an object as a 'donkey' or 'hammer') and domain level naming (naming the domain to which an object belongs to such as 'living' or 'manmade'). Both of these tasks produced more activation in the left fusiform area (relative to the right) compared to fixating a blank screen. Similar findings of increased activation in the left hemisphere to object naming were found by Moore and Price (1999b) with higher activation in left anterior and left posterior fusiform area to object naming compared to object viewing. In addition, Joseph (2001) reported that viewing, matching and naming tasks recruited different regions of the occipital temporal cortex. This evidence combined with the evidence that the left fusiform is sensitive to semantic manipulations suggests that neural populations in LOC may well respond differently depending on whether a task recruits semantic/language processes or not.

Also of interest, a number of studies have found a lateralized pattern of category-specific activation in the ventral visual pathway (Martin et al., 1996; Chao et al., 1999; Gerlach et al., 2002; Whatmough et al., 2002). Chao et al. (1999) contrasted activations to animals and tools on three tasks (viewing, matching and naming). They found that animal stimuli more commonly produced activation in the right superior temporal sulcus. In contrast, tool stimuli more commonly produced activation in the left middle temporal gyrus. Okada et al. (2000) found a similar pattern of lateralization to the naming of animals and tools. If activation associated with these categories is semantically driven then it is expected that there will be differences in the pattern of activation depending on whether the task requires semantic information or not.

Given that LOC is known to be sensitive to objects (Malach et al., 1995; among many others; Kanwisher et al., 1996; Grill-Spector et al., 1999, 2001, 2003) and identifying objects involves language processes, our study used functional imaging to investigate the effects a naming and a matching task had on the fMRI response in two sub-divisions of LOC. If LOC was sensitive to language processes, we expected more activation in left LOC for the naming task compared to the matching task. We examined both the anterior and posterior portions of LOC as Simons et al. (2003) found that only the left fusiform was sensitive to semantic manipulations involving language. We also examined the effects of the matching and naming tasks on the lateralization of category-specific areas in LOC by contrasting activations to three categories (animals, tools and letters).

2. Results

To identify object-sensitive brain areas, we presented our subjects with intact 2-D black and white line drawings of objects (animals, tools and letters) alternating with scrambled versions of the same images. In one sequence of three scans, subjects performed a matching task where they pressed a response key whenever they saw two-identical images, either intact or scrambled, in a row. In a second sequence of three scans, subjects silently named the same objects and passively viewed the scrambled objects.

The analysis of the fMRI response was performed on two subdivisions of LOC, namely LO (lateral occipital area) and pFs (posterior fusiform area), as illustrated in Fig. 1. To measure

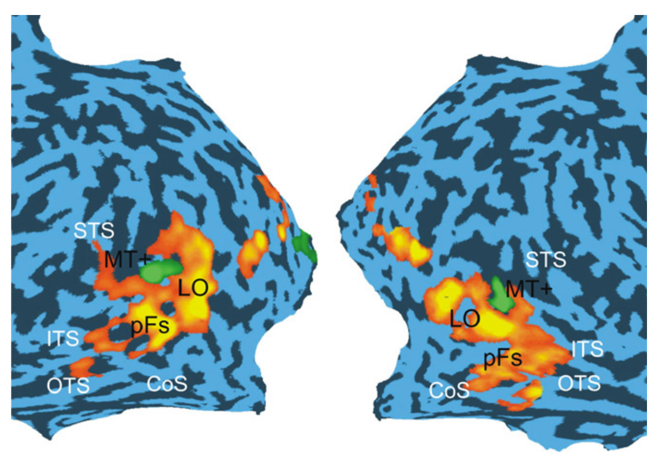

Fig. 1 – The fMRI response in two subdivisions of LOC. Both areas were defined functionally as a set of contiguous voxels with significantly stronger activation ($p<10^{-4}$) to intact versus scrambled objects. Area LO (lateral occipital area) was located posterior and lateral to MT+ (mean Talairach co-ordinates: right LO: −41.8±4, −72.3±8, −3.4±5, left LO: 41.3±2, −78±6, −1.85±3) and area pFs was located anterior to MT+, ventral to LO in the posterior to mid-fusiform gyrus, extending also into the occipitotemporal sulcus (mean Talairach co-ordinates: right pFs: −38.3±5, −58.4±5, −15.4±5, and left pFs: 37.3±3, −59.9±9, −14.6±5) (STS=superior temporal sulcus, ITS=inferior temporal sulcus, OTS=occipital temporal sulcus, CoS=calcarine sulcus).