

The Visual What For Area: Words and pictures in the left fusiform gyrus

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An area in the left fusiform gyrus labelled the Visual Word Form Area (VWFA) is claimed to be especially, or even selectively, responsive to words. We explored how stimulus type and task demands affect activity in this area by conducting a PET experiment where words and pictures were presented in two conditions that differed in demands on shape processing: colour decision and categorization. The subjects also performed an object decision task with pictures only. The imaging data revealed a main effect of stimulus type: rCBF was higher during word compared with picture processing. When compared individually for colour decision and categorization, the difference between words and pictures was only significant during colour decision, although a trend was present during categorization also. rCBF in the VWFA was highest during the object decision task, where only pictures were presented. Our findings indicate that the putative VWFA is activated more by written words than pictures, but only under certain circumstances. As demands on shape processing increase, the difference in activation between words and pictures decreases and can even be abolished. We suggest that activation in the VWFA could reflect shape configuration—the integration of shape elements into elaborate shape descriptions corresponding to whole objects or words. This process may be required to different degrees for pictures and words depending on task demands.

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Introduction

Recent functional imaging studies have identified a region in the middle part of the left fusiform gyrus which has been labelled the Visual Word Form Area (VWFA) (Cohen et al., 2000; McCandliss et al., 2003). It is claimed that this area is responsible

for computing representations of “abstract letter identities invariant for parameters such as spatial position, size, font or case” (Cohen et al., 2003; p. 1314). This claim is based on two main lines of argument. First, this area is activated by words and letter-strings as compared to rest, fixation, or viewing of simple patterns like checkerboards (Cohen et al., 2000, 2002). Secondly, this area in the left hemisphere is activated regardless of hemifield of presentation in tachistoscopic experiments, indicating that this activation represents processing of abstract, rather than stimulus specific, letter identities (Cohen et al., 2000). The VWFA has also been implicated in the disorder of pure alexia (Cohen et al., 2003; Gaillard et al., 2006), although this claim has recently been questioned (Hillis et al., 2005).

The existence of a cerebral area solely dedicated to processing of abstract letter or word forms, as well as the suggested name, has been challenged both on theoretical and empirical grounds (Price and Devlin, 2003, 2004), and it is still not clear which role this area might play in recognition of words and other visual stimuli. Depending on whether words, non-words, consonant strings or single letters are used, and what kind of stimuli they are compared to, the activation in the VWFA differs. The VWFA is quite consistently found activated when presentation of written words is contrasted with rest, fixation or simple visual patterns (Cohen et al., 2000, 2002), but this picture changes when letters and letter strings are contrasted with more complex stimuli, like pictures of faces (Puce et al., 1996) or objects (Joseph et al., 2003, 2006). For instance, in an fMRI study comparing processing of pictures of animals and single letters in passive viewing and silent naming tasks, Joseph et al. (2003) failed to find any fusiform area selectively activated by single letters. Also, Joseph et al. (2006) report that no area in the left fusiform gyrus is selectively activated by letters compared to pictures of objects when subjects perform a matching task. Single letter processing might not be a task that would activate the VWFA though, given that different parts of the fusiform gyrus are found activated when single letters are compared to letter strings (James et al., 2005, although see Joseph et al., 2006 for arguments to the contrary).

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Regarding *what* kind of word representation is computed in the VWFA, the picture is also unclear: While some studies find this area more activated by real words than consonant strings or pseudowords (Cohen et al., 2002), others have found that activity in the VWFA increases as word frequency decreases, and is highest for pseudowords compared to real words (Kronbichler et al., 2004). The authors of the latter study claim that this effect of frequency on activation in the VWFA indicates that this area contributes to the recognition of visual words in a manner that supersedes the creation of abstract letter representations. The VWFA has also been implicated in non-visual processing, like semantic processing or phonological retrieval (Price et al., 2003; Vigneau et al., 2005). The focus of the present paper is limited to the suggested role of the VWFA in visual processing.

As noted by McCandliss et al. (2003 p.294) “there is ample evidence that object and face recognition can also activate this area to varying degrees”, and, as pointed out by Price and Devlin (2004), studies are required to examine whether activation in this area is dissociable for words versus objects, and whether this might be dependent on task demands. Given the disparity of findings between studies comparing words to relatively simple visual stimuli versus studies comparing words to objects or faces, one could assume that activity in the VWFA is affected by visual complexity and demands on shape processing.

In order to investigate this hypothesis, we conducted a PET-study testing whether rCBF in the proposed visual word form area is greater for words than for pictures of objects, and whether this difference is modulated by the degree of shape analysis required to solve the task at hand. In the PET experiment, words and pictures were presented in two conditions that differed in demands on shape analysis: colour decision and categorization. During colour decision, subjects were to indicate whether stimuli were coloured white or yellow, a task requiring little shape analysis. In the categorization task, subjects had to decide whether stimuli represented natural objects or artefacts, a task placing higher demands on shape discrimination. The subjects also performed an object decision task, deciding whether pictures represented real objects or nonobjects. The nonobjects were chimeric line-drawings of closed figures constructed by exchanging single parts belonging to objects from the same category, which makes elaborate shape processing essential to perform this task (Gerlach et al., 2004, 2005). In addition to PET-measurements, we also recorded reaction times (RTs) in all tasks. Our general expectation was that demands on shape processing would influence rCBF in the VWFA. Because shape processing is required to different degrees in colour decision (where processing of shape is not necessary to perform the task) and categorization (where shape must be processed), we expected differences in rCBF in the VWFA, as well as in RTs between the tasks with pictorial stimuli. In the word-tasks, we expected the difference in rCBF between colour decision and categorization to be smaller, as reading—and thus the processing of word shape—is assumed to occur automatically, regardless of task demands (cf. the Stroop-effect, Stroop, 1935). Areas associated with conscious reading have also been found activated when words are presented subliminally (Dehaene et al., 2001), indicating elaborated processing even when subjects are unaware of seeing a word.

Thus we hypothesized that: (i) rCBF in the VWFA would be higher for words than for pictures during colour decision; (ii) this difference would diminish, as demands on shape processing increased, during categorization; and (iii) rCBF in the VWFA would be highest during object decision. We also expected reaction

times to reflect task difficulty, so that RTs would be slowest in the object decision task, intermediate during categorization and comparatively fast in the colour decision task.

Method

Subjects

12 right-handed healthy volunteers (6 female, mean age 24 (range: 22–28)) participated in this experiment. Informed written consent was obtained according to the Declaration of Helsinki II, and the study was approved by the local ethics committee of Copenhagen (J.nr. (KF) 11-100/00).

Cognitive tasks

The subjects completed three tasks: (i) colour decision (deciding whether stimuli were coloured white or yellow), (ii) categorization (deciding whether stimuli represented natural objects or artefacts), and (iii) object decision (deciding whether stimuli represented real objects or non-objects). In the colour decision and categorization tasks, stimuli were either words or pictures (in separate conditions). The object decision task was with pictures only. All tasks came in two versions: one with a predominance of artefacts presented in the critical scan window and the other with a predominance of natural objects (cf. the section on design). Altogether, subjects were presented with a total of 10 conditions (see Table 1). In addition, the subjects also performed four other tasks which will not be considered here as they have no bearing on the present experiment (results have been presented in Gerlach et al., 2006). Because the purpose of this paper is to examine effects of stimulus type (words vs. pictures) and shape analysis in the VWFA, the behavioural and imaging analyses were collapsed over category (artefacts and natural objects).

The order of tasks and conditions was randomized across subjects with the only constraint that all subjects first performed the object decision task. The subjects were encouraged to respond as fast and as accurately as possible. Before the actual experiments started, the subjects performed a practice version of each task while in the scanner. Stimuli from these practice versions were not used in the actual experiments.

All responses were made on a serial response box placed in front of the subjects' right hand. Half of the subjects used their index finger to answer for yellow stimuli (colour decision), artefacts (categorization) and real objects (object decision) and

Table 1
Cognitive tasks

Task	Condition	Stimuli
Colour decision	Pictures	Natural objects Artefacts
	Words	Natural objects Artefacts
Categorization	Pictures	Natural objects Artefacts
	Words	Natural objects Artefacts
Object decision	Pictures	Natural objects Artefacts

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