ELSEVIER

Neuropsychologia 44 (2006) 594–609

NEUROPSYCHOLOGIA

www.elsevier.com/locate/neuropsychologia

The fusiform face area is not sufficient for face recognition: Evidence from a patient with dense prosopagnosia and no occipital face area

Jennifer K.E. Steeves [a,∗], Jody C. Culham [a], Bradley C. Duchaine [b], Cristiana Cavina Pratesi [a], Kenneth F. Valyear [a], Igor Schindler [c], G. Keith Humphrey [a], A. David Milner [c], Melvyn A. Goodale [a]

[a] *Department of Psychology, The University of Western Ontario, London, Ont., Canada N6A 5C2*
[b] *Vision Sciences Laboratory, Department of Psychology, Harvard University, Cambridge, MA, USA*
[c] *Cognitive Neuroscience Research Unit, University of Durham, Durham, UK*

Received 24 February 2005; received in revised form 17 June 2005; accepted 30 June 2005
Available online 25 August 2005

Abstract

We tested functional activation for faces in patient D.F., who following acquired brain damage has a profound deficit in object recognition based on form (visual form agnosia) and also prosopagnosia that is undocumented to date. Functional imaging demonstrated that like our control observers, D.F. shows significantly more activation when passively viewing face compared to scene images in an area that is consistent with the fusiform face area (FFA) ($p < 0.01$). Control observers also show occipital face area (OFA) activation; however, whereas D.F.'s lesions appear to overlap the OFA bilaterally. We asked, given that D.F. shows FFA activation for faces, to what extent is she able to recognize faces? D.F. demonstrated a severe impairment in higher level face processing—she could not recognize face identity, gender or emotional expression. In contrast, she performed relatively normally on many face categorization tasks. D.F. can differentiate faces from non-faces given sufficient texture information and processing time, and she can do this is independent of color and illumination information. D.F. can use configural information for categorizing faces when they are presented in an upright but not a sideways orientation and given that she also cannot discriminate half-faces she may rely on a spatially symmetric feature arrangement. Faces appear to be a unique category, which she can classify even when she has no advance knowledge that she will be shown face images. Together, these imaging and behavioral data support the importance of the integrity of a complex network of regions for face identification, including more than just the FFA—in particular the OFA, a region believed to be associated with low-level processing.

Keywords: fMRI; FFA; OFA; Face recognition; Prosopagnosia

1. Introduction

Prosopagnosia is a neurological deficit characterized by an inability to recognize faces despite intact intellectual and cognitive function and spared early visual processing. Cases have been reported where this dissociation occurs with little or no impairment in visual recognition of other types of stimuli (e.g. Duchaine & Nakayama, 2005; McNeil & Warrington, 1993; Nunn, Postma, & Pearson, 2001; Whiteley & Warrington, 1977). Complementary cases have shown that the converse dissociation, normal face recognition with severe object agnosia, is also possible (Humphreys & Rumiati, 1998; McMullen, Fisk, & Phillips, 2000; Moscovitch, Winocur, & Behrmann, 1997) Prosopagnosia, however, may also occur in combination with other visual recognition deficits such as an inability to recognize objects and/or words (e.g. Damasio, Damasio, & Van Hoesen, 1982) or landmarks (e.g. Pallis, 1955). The nature of lesions associated with prosopagnosia has long been documented and anatomical and imaging data

∗ Corresponding author. Present address: Department of Psychology, Atkinson Faculty of Liberal & Professional Studies, York University, Toronto, Ont., Canada M3J 1P3. Tel.: +1 416 736 2100x20452; fax: +1 416 736 5662.
E-mail address: steeves@yorku.ca (J.K.E. Steeves).

0028-3932/$ – see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.neuropsychologia.2005.06.013

(CT, MRI and SPECT) from patients with prosopagnosia converge on bilateral inferior occipito-temporal cortical damage (see Farah, 1990 for a summary). This suggests that a relatively localized cortical area is involved in the inability to perceive faces. Whether prosopagnosia occurs in isolation or is accompanied by other agnosias presumably depends on the extent of the cortical damage.

Paralleling neuropsychological evidence, functional imaging in neurologically intact individuals shows discrete cortical areas that are significantly more active when passively viewing faces than other non-face stimuli such as objects (Kanwisher, McDermott, & Chun, 1997), letter strings (Puce, Allison, Asgari, Gore, & McCarthy, 1996) or houses (Tong et al., 2000). This area within the fusiform gyrus has been termed the fusiform face area (FFA) (Kanwisher et al., 1997). FFA activation correlates well with successful face processing but not with successful object processing (Grill-Spector, Knouf, & Kanwisher, 2004). Similarly, functional magnetic resonance imaging (fMRI) has shown other cortical areas to be selectively more active when viewing other classes of stimuli. This includes objects—the lateral occipital complex (LOC—an area comprising the lateral surface near the lateral occipital sulcus (LO), the ventral occipito-temporal regions (LOa/pFs) extending into the posterior and mid fusiform gyrus and occipito-temporal sulcus) (Grill-Spector, Kourtzi, & Kanwisher, 2001; Malach et al., 1995), scenes or places—the parahippocampal place area (PPA) (Epstein & Kanwisher, 1998), letter strings—the left occipito-temporal and inferior occipital sulci (Puce et al., 1996) and the human body—a region in the right lateral occipito-temporal cortex (extrastriate body area or EBA) (Downing, Jiang, Shuman, & Kanwisher, 2001). Early studies of face-selective activation in the cortex saw that, in addition to the FFA, other cortical areas were selectively active for faces, specifically in the superior temporal sulcus (STS) and in the inferior and mid occipital gyri (e.g. Halgren et al., 1999; Haxby et al., 1999; Kanwisher et al., 1997; Vaina, Solomon, Chowdhury, Sinha, & Belliveau, 2002), although in some studies these areas appeared to be less systematically activated (e.g. Kanwisher et al., 1997) or showed a weaker face-selective response (Gauthier et al., 2000) than the FFA. The importance of the inferior occipital area in face processing has been, until recently, somewhat overlooked for these reasons and also because it is a relatively "early" visual area in the ventral stream—earlier areas are assumed to perform lower level processing rather than higher level processing such as face recognition. Gauthier et al. (2000) termed the face-selective inferior occipital area that falls within the larger LOC region, the occipital face area (OFA).

Consistent with the notion of discrete brain areas for processing such image classes as faces, objects and scenes, behavioral evidence in neurologically intact participants suggests that qualitatively different cognitive processes are involved. For example, the attentional demands of scene and object processing appear to be different (Li, VanRullen, Koch, & Perona, 2002). Other behavioral measures show face-specific effects of visual processing that do not affect other image categories. For instance, rotating a face image upside-down disturbs face recognition ability more than object recognition (Yin, 1969). In contrast, the ability to classify a scene image correctly is not significantly affected by inverting it (Steeves et al., 2004). Further, face recognition appears to involve more holistic processing than object recognition, which can often operate using more part-based mechanisms. For example, individual parts of a face are more accurately recognized when presented within the whole face rather than in isolation. This is not the case for other types of stimuli such as scrambled faces, inverted faces or houses (Tanaka & Farah, 1993).

It seems intuitive to expect then that damage to these brain areas would result in domain-specific agnosias. To a certain degree, this does appear to be the case. Topographical agnosia patients, who have damage localized to the region of the PPA, are impaired in scene recognition but not object recognition and do not show functional activation for scene images in this brain region (Epstein, DeYoe, Press, Rosen, & Kanwisher, 2001). Consistent with this notion our research group recently performed magnetic resonance imaging (MRI) and fMRI scans on a patient, D.F. who suffers from profound visual form agnosia (a deficit in object recognition based on form). It was revealed that her area of damage overlaps with the object-selective lateral occipital area of the LOC in normal participants in both hemispheres (James, Culham, Humphrey, Milner, & Goodale, 2003). We also recently examined functional activation for scenes in patient D.F. and observed that despite an absence of object recognition she had relatively normal scene recognition ability and PPA activation (Steeves et al., 2004). In that paper, we also observed that D.F. showed what appeared to be normal functional activation for faces in an area consistent with the FFA. However, it has been informally noted that patient D.F. has an inability to recognize faces. If she cannot recognize objects and has no LO but can recognize scenes and has an intact PPA, why can she not recognize faces when she shows functional activation in the FFA? Here, we extensively examine her inability to recognize faces given that she demonstrates FFA activation for faces and find that D.F. has spared face categorization but no higher level face processing abilities. We speculate that since her bilateral LO lesions overlap with the OFA bilaterally, an intact network between the FFA and the OFA may be necessary to drive higher level face processing.

2. Methods

2.1. Patient history

D.F. is a female patient, age 47 years, who suffered brain damage as a result of accidental carbon monoxide poisoning at age 34 years. D.F. shows relatively normal perimetry for static targets in the central visual field up to 30° eccentricity but with some lower visual field loss. Details of extensive