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Inversion superiority in visual agnosia may be common to a variety of orientation polarised objects besides faces

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Abstract

Selective impairment in recognition of faces (prosopagnosia) resulting from certain localized cortical lesions has been advanced as an argument for a face specific brain module. The argument is claimed to be strengthened by the discovery of an inversion superiority effect in the recognition of faces by a prosopagnosic patient(Farah et al., Vis Res 1995b;35:2089–2093). The present paper reports an inversion superiority effect in the recognition of faces and shoes in a visual agnosic patient. The finding raises the possibility that several classes of orientationally polarized objects, of which shoes and faces are examples, will exhibit inversion superiority. © 1998 Elsevier Science Ltd. All rights reserved.

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1. Introduction

Two contrasting views of the relation between disorders of visual object recognition (visual object agnosia) and face recognition (prosopagnosia[1]) co-exist at present. One view argues that prosopagnosia reflects the existence of an autonomous processing system specifically tailored for faces [1,2]. A system functionally specialised for a class of input stimuli (with or without the underlying neural substrate), is often referred to as a module. The face module is sometimes defined not only by reference to the class of input stimuli but also to its characteristic processing strategies like holistic encoding [3].

An alternative view challenges the notion of a face module and claims that prosopagnosia is an extreme manifestation of damage to the object recognition system. Face processing deficits manifest themselves with stimuli that are visually alike and have to be discriminated among a set of highly resembling items [4,5]. Prosopagnosia is here seen as an extreme manifestation of visual object agnosia. Damasio et al. [6], stress the need to distinguish the different issues involved in face recognition related to visual stimulus properties, functional requirements and cognitive task demands. These happen all to be interlocked tightly in the case of face recognition. Understanding face recognition, its similarities and differences with object recognition requires insight into the components of the visual processing system and their interactions. Whether or not one wants to apply the notion of a face module to this possibly unique combination of demands on the processing system may in the end not be such an important matter.

There are at least two ways of examining what object and face processing abilities have in common. A well known approach in the neuropsychological literature is to look for material specific dissociations in the patients' recognition performance. Grusser et al. [7], McNeil and Warrington [8] and Farah et al. [2] found patients impaired in face recognition but not in object recognition and presented their results as supporting

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[1] Prosopagnosia is an ambiguous term as it can refer either to loss of familiair face recognition, the inability to associate a seen face with its representation in memory or to visual face agnosia, loss of the ability to individuate a face or to recognize an exemplar within the category faces.

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the existence of a neural structure dedicated for faces. These results would converge with the evidence for face specificity from single cell recording in the temporal cortex of monkeys [9,10]. The debate on the existence of neuroanatomical substrates specialised for faces versus other objects continues with recent fMRI studies [11]. The notion of a direct link between neuro-anatomical findings and functional processes remains however hasardous [12]. Cognitive psychologists have approached the issue of uniqueness of faces by studying whether some perceptual effects obtain specifically with faces in normal subjects. A prime example of such an effect is the inversion inferiority effect (the relative loss of performance with inverted as contrasted with upright faces) first reported by Yin [13]. He showed that upside-down inversion affected recognition performance for faces but not for other mono-oriented stimuli like houses.

Combining the notion of material-specific deficits in patients with the experimental dissociation between faces and other stimuli obtained in normal subjects, Yin [14] raised the question whether a specific kind of focal brain damage would eliminate the normal inversion effect. He reported that such was indeed the case for right posterior injuries. Subsequent studies have also used the inversion effect to study face impairments in clinical populations. Langdell [15] reported that autistic adolescents are better at recognizing upright than inverted faces [16].

Recently the potential contribution of the face inversion effect to the debate on the uniqueness of face was taken one step further by Farah et al. [1]. Their prosopagnosic patient LH did not show the normal face inversion effect, and was actually better with upside-down presentations, a phenomenon we will refer to as inversion superiority. Farah et al. [1] take this inversion superiority as support for a face module that continues to dominate face processing in spite of its impairment. As a consequence the intact general visual procedures the patient is using in successfully matching inverted faces cannot be used in the presence of an upright face. Farah et al. appeal to Fodor's notion of mandatoriness of modular processing.

Actually, the inversion effect itself is not limited to faces, even if it is strongest with face stimuli. Since Yin [13], inversion effects have also been reported for other visual materials like gundogs, handwriting, [17] but not landscapes or houses [18,19]. A methodological implication of using the inversion effect is that objects as well as faces must be studied with prosopagnosic patients before claims about the material specific impairments and uniqueness of faces can be based on face inversion superiority [20].

We have examined the effect of inversion on face and object recognition in a prosopagnosia and visual agnosia patient[1], using a task requiring matching of face and non-face stimuli. As nonface materials we chose shoes because they have potentially critical characteristics in common with faces: orientation polarity, high frequency of encounter, high familiarity, prototypicality, large number of exemplars and search for the singular exemplar. Just as for faces, discrimination among exemplars of shoes seems to require processing of differences in the local details as well as in the relations among them, suggesting that first order, as well as second order or relational properties play a role [18].

Two components have been reported to be critical for observing significant inversion effects, memory load and well developed face expertise [21]. Neither could be drawn upon with a face agnosic. Our study used a simultaneous match to sample task since also previous training and testing for recognition [3,22] was not feasable with our patient. Thus we needed to secure that with a simultaneous matching paradigm and entirely unfamiliar stimuli, there would still be an inversion effect in normal subjects.

2. Method

2.1. Participants

Patient BC is a 74 year-old retired secretary with bilateral lesions of the antero-inferior parts of the occipital lobes. She is severely impaired in visual identification of colors, of words, of faces and of common objects. In May 1995 AD suffered from a haematoma located across the left temporo-occipital sulcus, involving the middle occipital gyrus and the inferior temporal gyrus (Brodmann areas 18, 19 and 37). After some weeks, Goldmann perimetry showed a residual right paracentral scotoma, which disappears with IV/4 test. In December 1995 she suffered from a second, right-sided haematoma, almost symmetrical to the first. The lesion was centred on the middle occipital gyrus, just posterior to the temporo-occipital sulcus, involving area 19 and the white matter underlying area 18. Fig. 1 shows a T1-weighted MRI scan performed in March 1996.

In confrontation naming of faces, AD could only name one celebrity (Mitterand) out of 40, and she even failed to recognize her own husband. With photographs of unknown faces, she performed poorly in both gender decision (12/20 correct) and age decision (11/30). However, she was reasonably good at a face decision task requiring her to distinguish real from jumbled faces (14/20) (for other results on face and object recognition tasks not directly relevant here, see Bartolomeo et al. [23]).

With line drawings of common objects, she was strongly impaired in tasks of confrontation oral naming

(39/80 correct) and gave no alternative signs of recognizing (e.g. by miming of use) the objects she could not name. Pointing was similarly affected. Moving stimuli did not improve performance. She could not match pictures as to function (e.g. stamp–envelope) or category membership (fork–knife), but performed the same tasks flawlessly on the basis of oral presentations. Finally, tactile naming of real objects was intact, which confirms the specifically visual character of the deficits.

Tested with standard colour perception tests, AD was severely achromatopsic [24]. Her reading was slow and laborious and followed the typical letter-by-letter pattern of pure alexia. An interesting aspect of her profile of symptoms, which will not be considered in the present paper, is that mental imagery is largely preserved in the four domains in which she exhibits such strong perceptual deficits [23].

Twelve normal subjects, all undergraduate students at Tilburg University, were tested in Study 1 with standard computer presentation and short exposure times on both the faces and shoes materials, essentially to provide a normal baseline concerning the effects of inversion on identification of these two materials.

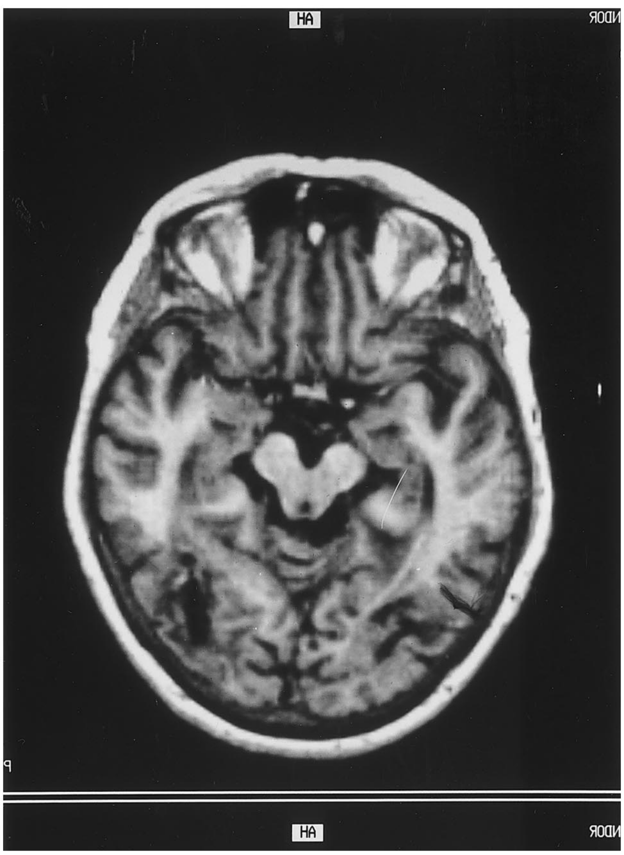

Fig. 1. T1 weighted MRI scan sowing symmetrical lesions in Brodman areas 1118 and 19 and in the underlying white matter. On the left side the lesion extends anteriorly to the inferior temporal gyrus (BA 37).

2.2. Materials and tasks

The main material consisted of photographs of human faces and of shoes. The faces were those of eight young male adults, each photographed once in frontal view and once in 3/4 orientation. For shoes, eight exemplars were similarly photographed once in upper front view, i.e. with the tip of the shoes pointing toward the camera, and once in 3/4 profile. The photographs were taken with a Canon Still Video Camera RC-560 and stored on video disc VF-50. They were presented either on a computer screen (Studies 1–2) or manually as 7×7cm black and white laser prints (Studies 3–4).

All materials were used in two different tasks.

In the ABX tasks (Studies 1 and 4), three pictures of the same type (faces or shoes, upright or inverted), one target and two probes, were presented simultaneously on each trial. The target picture was always a front view one, and the positive probe was the 3/4 profile view of the same person/shoes, while the negative probe represented a different person/pair of shoes. The target picture was presented above the two probe pictures shown side by side below the target. The task was to indicate the side occupied by the positive probe either by key pressing (Study 1) or by vocal response (Study 4).

In the AX task (Studies 2 and 3), two pictures of the same type were presented side by side and the patient was asked to say whether they represented the same person/pair of shoes or different ones. All trials involved two pictures taken from different angles (one front and one 3/4 profile) so that ‘Same’ trials never presented identical pictures. Testing was always run in separate and equivalent blocks of 20 trials, 10 ‘same’ and 10 ‘different’, for the different types of material. Blocks alternated between faces of shoe stimuli, upright and inverted. The experiment was preceded by eight practice trials (two of each stimulus type, see Fig. 2 for an example of each).

2.3. Procedure

Study 1 involved young normal subjects, and was run essentially to establish a baseline concerning normal performance with our material. It involved the two-alternative ABX task with computer representations and key pressing responses. Each subject performed four blocks of trials on the ABX task, one block with each of the four types of material (faces upright, face upside-down, shoes upright and shoes upside-down). The three pictures of each trial were presented simultaneously for 500 ms on the computer monitor, 500 ms after an auditory warning signal. The probe pictures were labelled A and B, and the same labels appeared next to the response keys.

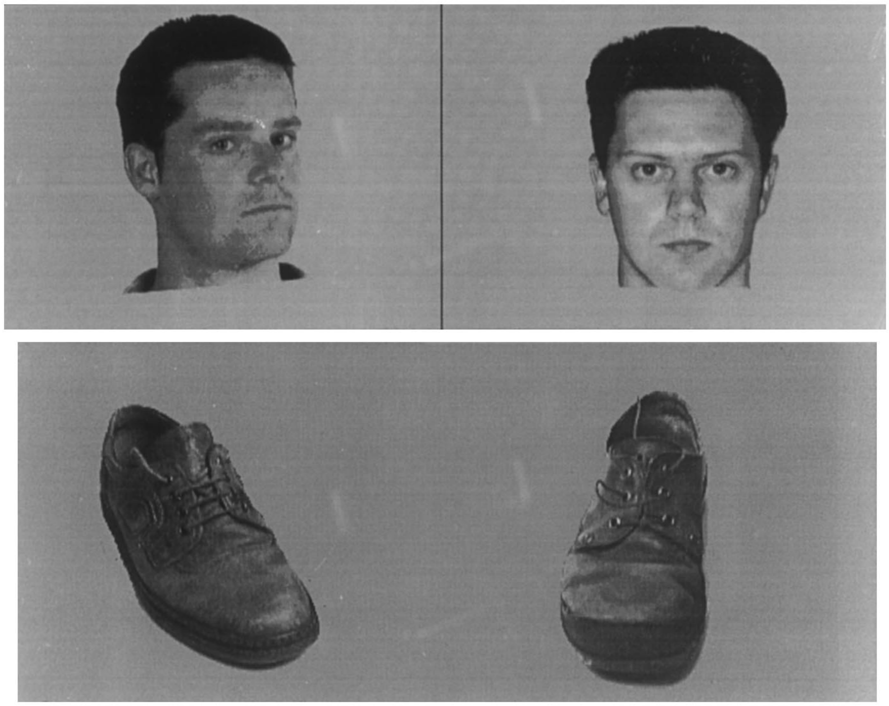

Fig. 2. Exemplars of face and shoe stimuli used in experimental tasks.

In Studies 2–4, patient AD was examined on the same material with both the ABX and the AX task. Our original plan was to test her throughout with computer presentations, just like the control subjects. That kind of situation however appeared to present special difficulties for her. As a consequence, in Study 2 we ran her with the hopefully easier AX task, in place of the ABX one, increased presentation time to 1500 ms and asked for vocal same/different responses instead of key pressing ones. Nevertheless, her performance was as we shall see at chance level with both faces and objects.

This result led us to conduct the further testing with a manual procedure, free vision and unlimited presentation time. In Study 3, which involved two sessions within one week's interval, AD performed the AX task twice with all pairs of stimuli presented manually and vocal same/different responses. In Study 4, she performed the ABX task with the same material, under the same presentation and responding conditions.

3. Results

The results are shown in Table 1. The normal subjects tested in Study 1 performed significantly worse ($t_{11} = 2.76$; $P < 0.02$) with inverted faces than with upright ones. They thus displayed the usual face inversion effect. With shoes, the effect of inversion was small and non-significant ($t_{11} = 1.02$; $P = 0.33$).

In Study 2, in which the stimuli were presented on the computer, AD's identification performance was at chance level with all types of material, and thus provided no useful information relevant to the aims of the study, apart from a slight suggestion of an improvement with inversion. The suggestion was however strongly upheld by the results obtained with manual presentations. AD's identification performance was strongly and significantly better with inverted stimuli than with upright ones for both faces and shoes. That pattern obtained both with the AX task (Study 3) and the ABX task (Study 4). It will be noted that for both materials, identification of upright items was at chance level, whatever the task.

4. Discussion

With both upright faces and upright shoes, the patient's performance was at chance level, confirming clinical data indicating object and face agnosia. But with the same material presented upside down, her performance was largely above chance. Thus she displays the inversion superiority pattern with both materials. These results are important for several theoretical and methodological reasons.

First, the finding by Farah and collaborators of better performance on inverted faces in a prosopagnosic patient is now replicated on another case. Moreover, the effect observed here is stronger, BC

Table 1
The results of studies 1–4 results of control subjects (study 1) and patient AD for shoes (upright/inverted) and face (upright/inverted) tasks.

Study	Task	Participants	Stimulus mode	Response	Shoes UP	Shoes DOWN	t/X2	Faces UP	Faces DOWN	t/X2
1	ABX	12 continued	PC	Key	58/80	53/80	$t_{11}=1.0$ 2 NC	62/80	55/80	$t_{11}=2.76$ $P<0.02$
2	AX	AD	PC	Key	32/80	48/80	X2 = 3.2 NS	36/60	48/80	X2 = 1.8 NS
3	AX	AD	Manual	Vocal	44/80	75/80	X2 = 15. 5 $P<0.001$	46/80	64/80	X2 = 4.7 $P<0.05$
4	ABX	AD	Manual	Vocal	31/60	60/60	X2 = 24.1 $P<0.001$	44/80	67/80	X2 = 26.7 $P<0.001$

performs at chance with upright faces whereas LH's performance was well above that level.

On the other hand, the fact that AD displayed inversion superiority to at least the same extent with another material creates a serious difficulty for the conclusions in support of a face module that Farah and collaborators have drawn from their result. The phenomenon is clearly not restricted to faces hence it cannot provide an argument for uniqueness.

It is important to note that it does not follow from our data that inversion superiority will obtain with any visual material for which a patient is agnosic. As mentioned in the Section 1, shoes were chosen in view of the fact that they share with faces some of the characteristics which according to Damasio and collaborators [25] make faces particularly susceptible when the object recognition system is impaired. Future investigations using a larger sample of materials, should provide information on the exact conditions on which inversion superiority depends.

Whereas both faces and shoes can give rise to inversion superiority in visual agnosics there is a potentially important difference between these two cases. Normal control subjects had inversion inferiority for faces but not for shoes. Thus inversion superiority can occur in patients for materials which do not produce inversion inferiority in normals. This creates a difficulty for Farah et al.'s assumption that inversion superiority in patients is somewhat in continuity with inversion inferiority in normals.

If one leaves aside the assumed implications for uniqueness and face modularity, the mechanism of inversion superiority put forward by Farah et al. is rather convincing. They propose that with upright faces the damaged recognition module still dominates the processing, thus standing in the way of the intact general identification system. Inverted faces on the other hand do not trigger the face module, allowing the general operations to control processing. Can this explanation integrate the present data of an inversion superiority for shoes?

The above explanation starts from the well-known fact that prosopagnosics can still sort faces from other objects [6,26]. Such preserved access to structural object representations in the absence of subsequent object recognition also been observed in visual object agnosics of the associative type like our patient [27]. She performs reasonably well on a face or object decision task and she has fluent drawing and copying skills, all typically lost in cases of apperceptive agnosia as well as integrative agnosia [28]. Evidence for spared access to structural form representations was also provided by in a study of depth segragation. Presented with a figure/ground segregation task which required her to indicate whether an object is present in the white or in the black part of the display, BC indicated systematically the correct part without however recognizing any object [29].The continuing dominance of the damaged identification system also argued by Farah et al. [1] might equally make sense in the case of object inversion superiority and a damaged object recognition system. Many studies of context effects in object perception with normal subjects have established that visual features are processed differently whether or not they belong to a meaningful whole or Gestalt. The most widely accepted contrast is between configuration based and analytical processes (e.g. Pomerantz in Kubovy and Pomerantz [30]; Suzuki and Cavanagh [31]; Mermelstein et al. [32]). If the patient continues to access structural form such context sensitive or configuration based processes will be triggered and intact analytic processes will be over-ruled.

This suggests that in patients suffering from so called integrative agnosia who have lost access to structural object form and only remain able to perform part-based operations like HJA for faces and objects [33] or CK for objects [34] would not show dominance of structural object representations and would thus not show inversion superiority. It may be the case that Farah et al. [2,1], are implicitly referring to processing strategies that in their view are not just configurational, but more than that, are entirely special for faces, like holistic processing [3]. But the issue of the actual processes involved in upright versus inverted face and object matching cannot be addressed by the inversion experiments at stake here. Our results do suggest though that the contrast between processes involved in face recognition versus object recognition cannot drawn along the lines of configuration based versus part-based procedures. Configuration-based processing appears clearly to matter also for object recognition.

We do not want to argue that the present result settles the debate about face specific processes one way or the other. For the time being we only conclude that inversion superiority does not constitute the crucial experiment.

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