Configural face processes in acquired and developmental prosopagnosia: evidence for two separate face systems?

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Configural face processes were tested using face recognition and face detection tasks in a comparison of acquired and developmental prosopagnosia. In the recognition task the two patients showed a very different pattern. The developmental patient does not show an inversion effect while the acquired prosopagnosia patient is better at matching inverted than normal stimuli. Moreover, there is no effect of face context on matching features in the developmental case while the acquired prosopagnosia patient shows a strong negative effect of context. However, in a speeded face detection task both patients are similarly unimpaired. The results are consistent with the existence of two separate face systems, one involved in face detection and the other in face recognition. *NeuroReport* 11:3145–3150 © 2000 Lippincott Williams & Wilkins.

Key words: Face context effect; Face detection; Face recognition; Inversion effect; Object recognition; Prosopagnosia

INTRODUCTION

Recent brain imaging studies have provided evidence for a dedicated brain area for faces but have not yet clarified its functional significance. It is unclear whether this area is involved simply in detection of the presence of a face-like pattern, in recognition of an individual face or in both. It is equally unclear whether configural processing, which is the hallmark of face operations is hardwired and modular or shaped by experience. Studies of prosopagnosic patients are crucial for drawing attention to separate components of the face mechanism that may have a different functional and neuro-anatomical basis but are difficult to pull apart in normal adults. Best known are cases of prosopagnosia acquired in adulthood (AP). Of particular importance, though little studied, are cases of congenital of developmental prosopagnosia (DP), a face specific deficit following from anomalous brain development. Cases of DP offer a window into the face system before it is fully established [1–6]. Our study presents the first systematic comparison of a case of AP and one of DP and it focuses on the critical ability of configural face perception.

The phenomenon which is best known for studying the face configuration is the inversion effect [7], traditionally defined as the fact that normal adults are better at matching upright than inverted faces (hereafter the face inversion inferiority effect). The standard explanation is that individual face recognition relies on configural operations of a canonically oriented face and these operations become ineffective when faces are presented upside down. AP patients who can no longer recognize individual faces are expected to loose the inversion inferiority effect; however, recent data showed that the face recognition deficit of AP is not exhaustively defined by loss of configural face processing. Some AP present the opposite pattern and perform better with inverted than with upright faces [8]. Instead of the inversion inferiority effect of normal viewers, they show an inversion superiority effect [9]. Since inversion superiority indicates the presence of configural face recognition its persistence after loss of face recognition presents a problem for theories which assume that face recognition and configural processes are closely linked. Instead, the inversion superiority effect provides evidence that in AP a profound recognition deficit coexists with preserved processing of the face as a configuration, therefore the link is a counterproductive one. To understand this situation we turned to DP.

In a typical DP patient face recognition processes and the configural operations normally associated with it do not develop. Thus one prediction is that such patients will show neither normal nor paradoxical configuration effects. Another aspect of the face mechanism less studied than recognition, at least in normal adults, concerns the early operations of detection of a face-like stimulus. Newborn babies attend selectively to face-like patterns, a preference that is likely to be based on crude and possibly sub-cortical mechanisms since temporal-occipital areas involved in object and face recognition are not yet sufficiently developed at birth and are presumably established under the influence of exposure to faces [10,11]. Johnson and Morton [10] argued for two separate systems, one involved in same species recognition (the 'Conspec' system) and the other dedicated to individual recognition (the 'Conlearn' system).

This two-systems view has not yet been applied to integrate the findings on neonatal face preferences with adult face recognition skills and with the pattern of deficits in AP and DP. Making this connection allows us to formulate some predictions on configural face operations involved in learned face recognition and in simple face detection. If a detection system is the first stage of the face mechanism, the same configural operations (or their deficits) should be similarly present in detection and recognition tasks. However, the results presented in this paper can best be explained by taking a different route and assuming two separate face systems and two different notions of configuration. We shall argue that the contrast between the AP and DP case in recognition performance is consistent with the role of experience for configuration implicated in recognition but that the similarity between the two cases argues for a different notion of configuration at stake in face detection.

SUBJECTS AND METHODS

Case presentations: Patient RP is a 49-year-old man who suffered a closed head injury at 6 years old and has not regained the ability to recognize faces since his accident. VA is a 42-year-old man without any history of neurological disorders. As is to be expected in cases of DP (see [1–5]) and in AP caused by closed head injury (see for example CK [12]) an MRI scan did not yield evidence of brain damage. An MRI scan of AV did not provide any indication of a lesion (for RP see [13] and for AV see [14]). The two patients have an unproblematic educational history and professional career. Intellectual abilities are well above average. They have no visual deficits but are severely impaired in face recognition without any clinical indication of object recognition difficulties. Both patients were examined with clinical face and object recognition tests (Table 1). Familiar face recognition was studied with photographs, caricatures and cartoons and was severely impaired. Neither AV nor RP could recognize faces from caricatures (for example, Fidel Castro from his beard). Both patients also failed to recognize well-known [12] cartoon characters (for AV 14/25 and for RP 2/15) but sometimes correctly identified the animal on which the cartoon figure was based (for example, pig head for Miss Piggy).

The clinical test data were complemented with more thorough information of the patients' categorization skills obtained in a preliminary experiment. Depending on the condition, participants were instructed to respond as fast as possible to the presence of a face, a shoe or a house. Distractors consisted of faces, shoes, houses and also cars. Subjects were asked to press the rightmost key on the response box to indicate the presence of a target category and the leftmost key for any other stimulus. As can be seen in Table 1, patients performed similarly to controls. Their performance was not based on laborious analysis of the pictures as latencies were within normal range.

Experiment 1: the inversion inferiority effect: The face inversion inferiority effect is already observed at around 6 years of age, although configural face processes continue to develop, as manifest by an inversion inferiority effect that is stronger in older children [15]. Therefore, if brain damage occurs at an age when the inversion inferiority effect is already present, as is the case in patient RP, there

Table 1. Performance of patient RP and AV on standardized visual processing tasks.

	Normal individuals	RP	AV
Low level visual processes			
Benton Visual Form discrimination		Normal	Normal
Benton line orientation		Normal	Normal
Birmingham Object Recognition Battery			
line length (test 2)		Normal	Normal
size (test 3)		Normal	Normal
orientation (test 4)		Normal	Normal
gap (test 5)		Normal	Normal
overlapping shapes (test 6)		Normal	Normal
minimal feature match (test 7)		Normal	Normal
foreshortened views (test 8)		Normal	Normal
object decision (test 10)		Normal	Normal
Object recognition			
Boston Naming Test		56/60	57/60
Snodgrass and Vanderwart picture naming (1980)		115/120	118/120
Face recognition			
Warrington		32/50	34/50
Benton		31/54 (severely impaired)	34/54
Categorization			
Face	36/36 (429 ms)	17/18 (764 ms)	35/36 (579 ms)
Shoe	35/36 (459 ms)	16/18 (970 ms)	31/36 (581 ms)
House	35/36 (449 ms)	18/18 (759 ms)	36/36 (544 ms)

could be residual configural processes and this would lead to a paradoxical configuration effect (as was previously found for adult DP patients AD and LH). In contrast, patient AV was never able to recognize individual faces. Besides AV and RP, a group of 24 students (half of them male) served as control subjects and received credit for their participation.

Stimuli consisted of photographs of 16 faces (half male) and 16 shoes. Viewing distance was ~50 cm, so that the stimuli subtended between 7° and 8° of visual angle for length and width. A stimulus consisted of three pictures (a frontal view combined with two 3/4 pictures), one of the same and the other of a different face or object. These triads were presented with either all pictures upright or all inverted. Trials were blocked by stimulus class and orientation. The experiment was repeated with reversed block order, making a total of 128 trials per experiment. Subjects were instructed to choose as fast as possible whether the left or right face or shoe was the same as the one at the top by pressing the corresponding key. In the simultaneous condition stimuli remained on the screen till key press. In the delayed condition the target frontal picture was presented for 2500 ms and the two probes were shown after a 2500 ms delay. RP was tested with the manual version of the task [16].

Experiment 2: the role of context in part recognition: The results obtained with the paradigm of inversion superiority indicated whether or not the upright face is still processed as a configuration but they could only provide indirect evidence about the processing of parts. A paradigm suited for studying the use of parts is that of the face context superiority effect, which is defined as the fact that presentation of a face part in the context of a normal upright face facilitates recognition of that face part [17]. We predicted that RP would either not show this effect or that he might show the opposite pattern, a face inferiority effect. This would mean that he would be inhibited by the normal face context but not by the context of an inverted face. Since in Experiment 1 AV showed neither an inversion inferiority nor an inversion superiority effect, we predicted that here also he would not be sensitive to the configuration of the whole stimulus when matching one of its parts.

A total of 32 frontal view gray-scale pictures of faces and houses were used. Part stimuli consisted of either a pair of eyes or a mouth, or the door or upper window. A trial consisted of a whole stimulus (one of 16 face images and eight house images) combined with a set of two part stimuli, taken from the target image and from a distractor. Subjects were instructed to press either one of two buttons corresponding to the left or right part probes. Stimuli were presented upright and inverted, resulting in a total of 64 trials per experiment. Trials were blocked by stimulus class and orientation. Half of the trials of each block was presented first, with reversed block order in the second half of the experiment. There were two conditions (simultaneous and delayed matching) and duration of stimulus presentation was identical to that in Experiment 1.

Experiment 3: face detection: Face and non-face stimuli were presented either under very short exposure conditions followed by a mask or with unlimited viewing time. Both patients and a new control group ($n = 17$) were presented with the detection task.

A prototype face served as a frame into which one of a set of six pairs of eyes and one of six mouths were put, making for six different faces or scrambled faces. At a viewing distance of 50 cm the stimuli extended ~7° × 9° visual angle. Faces and scrambled faces were presented in random order. Stimuli appeared randomly at one of 12 possible locations. In the unlimited time condition a trial started with a warning signal, and after 500 ms the stimulus was presented until response. In a second and third condition presented the same stimuli were presented once for 200 ms and once for 50 ms, immediately followed by a mask. Twenty-four trials were presented in each condition. Order effects were avoided by running a repeated presentation of each experiment in reversed order. RT was measured from stimulus onset.

RESULTS

In Experiment 1, controls showed the expected pattern of better performance with upright than inverted faces, both in accuracy ($F(1,23) = 17.81$, $p < 0.001$) and in latency ($F(1,23) = 13.77$, $p < 0.001$). They also showed increased latencies with inverted compared with upright shoes ($F(1,23) = 7.96$, $p < 0.01$). For the delayed condition the face inversion effects were equally significant in accuracy ($F(1,15) = 66.19$, $p < 0.001$) and latency ($F(1,15) = 21.6$, $p < 0.001$). Latencies were also shorter with upright than with inverted shoes ($F(1,15) = 7.15$, $p < 0.018$).

In the simultaneous matching condition patient RP was better at matching inverted than upright condition as shown by faster ($t(44) = 9.13$, $p < 0.001$) and better performance ($\chi^2(1) = 11.13$, $p < 0.001$) with the inverted faces, as well as faster performance with inverted shoes ($t(60) = 2.82$, $p < 0.006$). In the delayed condition RP showed impaired face matching performance, with both slow responses and considerable errors. There is an inversion superiority effect with the faces, both in latency ($t(44) = 7.53$, $p < 0.001$), and in accuracy ($\chi^2(1) < 4.95$, $p = 0.039$). RP was faster also for matching inverted than upright shoes ($t(54) = 5.88$, $p < 0.001$). In contrast, patient AV showed no inversion effect in simultaneous matching (Table 2). In the delayed condition he showed the same low accuracy as RP, but with considerably faster responses and he showed no significant effect of orientation. AV showed a trend of faster responses with upright faces ($t(95) = 1.81$, $p = 0.07$).

In Experiment 2, face parts but not house parts were recognized faster when presented upright than inverted ($F(1,23) = 8.12$, $p < 0.01$). In the delayed condition controls showed no effect. Patient RP was significantly faster with inverted faces (for simultaneous matching $t(59) = 4.10$, $p < 0.001$; for delayed matching $t(41) = 13.14$, $p < 0.001$). He was also slower with upright than inverted houses ($t(40) = 5.81$, $p < 0.001$). AV did not show an effect of orientation in either condition and responded equally accurately and with a trend for shorter latency to upright than to inverted faces ($t(93) = 1.92$, $p < 0.06$; Table 3). There was no difference between upright and inverted houses for AV.

Our next question was whether RP's paradoxical recognition performance would extend to a task which no

Table 2. Matching faces and shoes.

	Simultaneous		Delay	
	% correct	Reaction time (ms)	% correct	Reaction time (ms)
Controls				
Faces upright	96***	1363***	94***	834***
Faces inverted	92	1920	81	959
Shoe upright	95	869**	94	729*
Shoe inverted	94	973	94	773
AV				
Faces upright	91	3563	81	1651
Faces inverted	88	3897	70	1835
Shoe upright	97	2013	95	1217
Shoe inverted	100	1856	91	1172
RP				
Faces upright	63***	6661***	59*	4425***
Faces inverted	91	3847	84	3133
Shoe upright	97	2538**	88	2737***
Shoe inverted	97	2152	88	2083

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 3. Matching faces and houses.

	Simultaneous		Delay	
	% correct	Reaction time (ms)	% correct	Reaction time (ms)
Controls				
Faces upright	98	1773**	81	1275
Faces inverted	97	1955	81	1241
Houses upright	98	1138	84	1081
Houses inverted	98	1163	84	1070
AV				
Faces upright	75	3350	75	1680
Faces inverted	91	3372	73	1875
Houses upright	100	2119	91	1424
Houses inverted	97	2330	83	1445
RP				
Faces upright	94	4347***	63	4189***
Faces inverted	97	3738	72	2184
Houses upright	97	1522	59	3553***
Houses inverted	97	1618	72	2404

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

longer requires face recognition but only speeded detection of the presence of a face. Likewise, does AV's insensitivity to the face configuration so far shown in recognition tasks also extend to face detection? As expected controls performed very well in all conditions in Experiment 3 (Table 4), and there was no main effect or interaction effect of condition. AV performed at ceiling with unlimited viewing time and was still very good at 200 ms. His RTs were also within normal range. Since 200 ms is not enough to search for separate features and their location, AV's good and fast performance on these conditions indicates that in this decision task, in contrast with the recognition task, he uses the face configuration. At 50 ms presentation, AV's performance dropped but was still far above chance. RP showed good performance with 200 ms and even with 50 ms presentation time, but in the unlimited time condition latencies sharply increased for RP and accuracy decreased. On inspection it appears that this very poor performance is specific for the normal face condition.

The finding that both patients show overall good performance on the speeded detection task indicates responses coming from a configural face system [18]. In contrast, RP showed longer latencies and decreased accuracy with unlimited presentation and unmasked faces suggesting that with long exposure times his impaired face recognition system is activated. This interpretation is consistent with the results of Experiment 1 and 2 where RP showed an interference of normal configuration whereas AV did not.

DISCUSSION

Control subjects showed the expected inversion effect both in accuracy and latency even in a simultaneous matching task. The inversion effect for objects is consistent with

Table 4. Face detection.

	Unlimited time		200 ms		50 ms	
	% correct	Reaction time (ms)	% correct	Reaction time (ms)	% correct	Reaction time (ms)
AV						
Face	92	809	100	616	92	756
Scrambled face	100	795	96	689	46	839
RP						
Face	42	9305	100	1728	100	1280
Scrambled face	100	1911	92	1603	75	1212
Controls						
Face	88	573	91	551	92	505
Scrambled face	98	556	95	520	92	574

evidence for the role of canonical orientation on object recognition [19,20] and with data showing the importance of configural information in object recognition [21,22].

Patient RP displayed a better performance with inverted faces replicating previous inversion superiority results obtained with LH [8,9] and AD [16]. In contrast, patient AV showed neither an inversion inferiority nor a context superiority effect. As noted previously [16], the fact that the paradoxical inversion effect generalizes to objects refutes the argument originally put forward by Farah *et al.* because it shows that paradoxical inversion performance is not a sufficient basis for claiming face specificity. However, it should be stressed that this debate concerns face configuration as involved in recognition.

As predicted, normal subjects showed a face context superiority, indicating that the presence of the face context facilitates parts recognition, at least in the simultaneous task. In the delayed task subjects can overcome the context effect and successfully focus on the relevant face part. Patient AV is insensitive to the face context one way or the other and performs at the same level in the two conditions. On the other hand, RP shows the opposite of normal subjects and is inhibited by the normal face context. We thus find a difference between the DP and AP cases that is similar to that of the previous experiment. The data of RP again underscore that there are residual configural operations in the absence of recognition. The results also add a new element by showing clearly that parts-based strategies do not automatically compensate for the loss of face recognition contrary to what is often assumed [12]. Consistent with the data from the previous experiment, AV only has parts-based strategies available and applies these indistinctly to upright and inverted faces.

We studied configural face operations in a DP and an AP case with face recognition and face detection tasks. In the recognition tasks the DP showed neither an inversion superiority nor an inferiority effect. Neither did he show facilitation or an inhibition from the face context when matching face parts. But the AP case showed a strong influence of residual configuration both as an inversion superiority effect and as a context inferiority effect. In contrast, both patients show evidence of normal use of configuration in the face detection task except that with unlimited exposure duration RP can no longer perform the task.

Our data are consistent with a two systems model of the face mechanism based on the distinction between a hard-wired detection system ('Conspecifics') and a learned recognition system ('Conlearn') along the lines of the developmental model of Johnson and Morton [10]. We would like to argue that a two systems model is not only useful for studying the development of the face mechanism but can also account for patterns of breakdown. Once the recognition system is in place, it is difficult in normal adults to pull the two systems apart. But the primitive detection system may still be present in prosopagnosia, whether AP or DP, and be activated normally even if the recognition system is impaired (as in RP) or absent (as in AV). This hypothesis of separate systems is different from an explanation based on the notion of a breakdown of configural processes within one and the same face system [8].

In our view a single notion of configuration corresponding to a single system responsible both for detection and recognition cannot account for the present data, since AV shows a configuration effect in detection but not in recognition. Likewise, RP has normal face detection but a negative effect of configuration in recognition.

Moreover, the two systems approach provides possible explanations for the paradoxical inversion superiority and context inferiority effects observed in recognition tasks with AP patients (see also [9,25]) but not with the DP patient. Since these two effects were found in recognition tasks they indicate that face learning is important for configural processes in recognition but not in detection. A further possibility is that those paradoxical effects in recognition result from the interaction between configural processes of intact face detection with impaired face recognition. On this picture the intact configuration sensitive operations at the basis of face detection activate face recognition system (if present), and thereby prevent that the face stimulus is analyzed by alternative feature-based operations.

Studies of the neuro-anatomical basis of face processes are not incompatible with the notion of two separate face systems. Cells responding to the presence of a face have been found in other brain areas besides the fusiform gyrus [23,24] and may implement a much more crude and experience-independent mechanism responding to the presence of a face outline. On the other hand recent evidence indicates that the area in the fusiform gyrus activated to face recognition is very close to areas found for recognition of a variety of control objects. Thus the detection system may be more face-specific than the recognition system.

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