STRUCTURAL ENCODING PRECLUDES RECOGNITION OF FACE PARTS IN PROSOPAGNOSIA

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The extent and the impact of spared processing of facial stimuli in the prosopagnosic patient LH is examined using the inversion effect and the face context effect. Our study asked how the deficit in individual face recognition is related to two perceptual abilities that are spared in this patient but between which there is interference when both are applied to the face stimulus, i.e. structural encoding of the face and parts-based matching procedures. Three experiments studied this relationship with task demands and stimulus properties designed to trigger the parts-based processes. In the first experiment, human and animal faces are presented upright or inverted with good performance only for the inverted condition. In Experiment 2 normals show a clear face context effect (matching of upright faces easier than scrambled or inverted ones) in the full face matching task whereas in the parts matching task the face superiority effect disappears. In contrast, LH shows a face inferiority effect when matching full faces but also when matching an isolated face part to a face part in a full face context. The results show that structural encoding of the face overrules parts-based procedures that could otherwise be helpful to tell individual faces apart.

Prosopagnosia is a deficit in face recognition (Bodamer, 1947), whereby the face no longer elicits any sense of familiarity although the patient continues to recognise familiar voices or gait. How specific to faces this disorder is, is still controversial, partly because very few cases of prosopagnosia have been studied in such a way that the possibility of at least some mild deficit in other areas like word or object recognition can be entirely excluded (Bruce & Humphreys, 1994; Farah, 1990; Gauthier, Behrmann, & Tarr, in press). The debate is now broadened by contributions from electrophysiological studies (see Jeffreys, 1996) and from brain imaging methods (Gauthier, Tarr, Anderson, Skudlarski, & Gore, 1997; Kanwisher, McDermott, & Chun, 1997a). Recent reports have provided evidence that loss of normal face recognition can manifest itself not just as a loss of the normal pattern of performance—for example, better performance with upright than with inverted faces—but as its opposite, superior performance with inverted in contrast to upright faces (de Gelder, 1999; de Gelder, Bachoud-Levi, & Degos, 1998; Farah, Wilson, Drain, & Tanaka, 1995). In other words, these patients present us with a reversal of the normal pattern. This data suggests that loss of face processing ability is not simply a matter of losing the ability to process a certain category of stimuli (faces) nor of losing a certain processing style (one which targets the stimulus configuration), but that there is an interaction between damaged and intact skills. In order to focus on this interaction we refer to the intact aspects of face processing as "structural encoding" of the face. It is

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important to note that in this paper the term "structural encoding" does not refer specifically to one or another theory of face recognition. The present paper investigates the hypothesis that spared structural encoding renders the patient unable to apply parts and feature-based matching strategies to faces. The robustness and generality of this effect is shown in three experiments.

INTRODUCTION

A perspective common to many studies of prosopagnosia is that the deficit is situated at the within-category level and that face categorisation itself or the ability to make a face decision is intact. In terms of the popular model of Bruce and Young (1986), loss of face recognition ability corresponds to damage to the "face recognition units," leaving intact the earlier stages of face processing. The fact that recognition at the individual or exemplar level is critical for face recognition led to the "individuation" theory of prosopagnosia (Moscovitch, Winocur, & Behrmann, 1997) or the view that prosopagnosia is a deficit of within-category discriminations, defended by Damasio (Damasio, Damasio, & Van Hoesen, 1982; Damasio, Tranel, & Damasio, 1990). Like the model of Bruce and Young, this view assumes that prior to individual identity recognition, visual face processing is intact in prosopagnosics. The concept of structural encoding will be used throughout this paper to refer to this initial face categorisation stage because it is more general than some of the specific notions advanced to explain face processing (see following).

A family of more or less related theories of normal face recognition has focused on within-category processes of face recognition. A common theme is that the whole face is more than the parts, but there is no consensus as to what is exactly meant by "*whole*." One view is that the face initially consists of clearly separate parts or primary features, which when integrated give rise to the second-order features or to recognition of the face as a configuration (the spatial relations between the individual features), as argued by Rhodes and colleagues (Rhodes, 1988; Rhodes, Brake, & Atkinson, 1993). A stronger claim, made by Farah and collaborators, is that face recognition does not start from the encoding of separate face parts or initial parsing but that the face is represented holistically such that its parts are not represented other than in the whole context (Farah, 1990; Tanaka, & Farah, 1993). Finally, developmentalists have argued that, at the entry level, faces are encoded the same way as any other object by attending to the relations between the parts or to the overall configuration. From there develops the ability to use second-order facial information, which underlies individual face discrimination (Carey & Diamond, 1994; Diamond & Carey, 1986). As Moscovitch et al. (1997) remark, these different theories each address slightly different questions. Nevertheless, fine details aside, each of them suggests just what might be lost in prosopagnosia: loss of configuration-based processes in the sense of Rhodes et al., loss of the face module or of holistic processing in the sens of Farah et al., or loss of face expertise related to second-order representation of individual differences.

A critical question for grasping the differences between these three views concerns what is then spared in prosopagnosia. If second-order or configuration-based processing is lost, is what remains the recognition of isolated face parts? Or, once the face module is lost, are faces processed like objects, in a parts-based way? Or again, is face expertise—or the ability to use second-order relational information—lost but are faces still processed as bundles of first-order relational information just like objects? This latter view is in line with the consensus in the literature that prosopagnosic patients have lost the ability to discriminate between faces but continue to categorise faces normally. Thus, the notion that first-order information is spared and second-order information is lost (in Carey's terms) reflects a certain consensus concerning the pattern of spared and lost skills in prosopagnosia.

Recent studies of prosopagnosic patients have looked at this issue in more detail, complementing traditional clinical tests of intact face decision with behavioural tasks that have shown strong face-specific perceptual processing effects, like the inversion effect, in normal subjects. But studies have revealed a paradox, because some prosopagnosic patients are considerably better at matching inverted than upright faces (de Gelder et al., 1998; Farah et al., 1995).

The Paradox of Inversion Superiority

The inversion effect, first reported by Yin (1969) for normal subjects, has often been referred to as a benchmark for establishing normal face processing (Yin, 1970). Normal subjects are better at recognising, matching, and remembering a pair of faces when these are presented upright than when upside-down (Yin, 1969). Recently Farah et al. (1995) have studied the inversion effect in prosopagnosic patient LH. Following the results obtained with right-hemisphere deficits the prediction was that LH would perform the same way with upright and inverted faces. But instead, LH showed face inversion superiority. We have confirmed this finding and at the same time extended it to objects with agnosic patient AD (de Gelder et al., 1998). Subsequently the same effects were observed with LH (de Gelder, 1999). This reversed face inversion effect cannot be reduced to absence of the normal pattern. This finding challenges the notion that the ability to use second-order relational information is lost and is subsequently compensated for by using intact feature-based routines to discriminate faces.

Instead, the paradox of inversion superiority is that individual face recognition is lost but that some aspects of face processing are still active and interfere with reliance upon general visual routines in order to discriminate individual faces. Thus, when the normal pattern of better performance with upright faces is reversed, more seems to be at stake than just spared face categorisation in the presence of lost second-order or within-category discrimination. Somehow these patients are handicapped by their spared face categorisation and prevented from using intact parts-based processes with faces. The latter are successfully used with inverted faces but are clearly of no use to deal with an upright face. Presumably inverting a face makes it object-like and no longer triggers face-specific processes, therefore giving a chance to part-based routines. The present study reports experiments designed to test the robustness and generality of this paradox.

Spared Structural Encoding in LH?

The case of patient LH is well suited for examining the relation and the interference between spared first-order categorisation and parts-based processes. Inversion superiority was reported for this patient but there is inconsistency in previous studies of LH concerning the issue of configuration-based processing. An older study by Levine and Calvanio (1989) argues (p.151) that the core of LH's problems with faces is an inability to get "an overview of sufficient features of a stimulus to allow the structuring or crystallisation of a coherent percept" and that LH's disorder is one of "defective visual configural processing." These authors go on (p.161) to propose that "defective configurational processing is characteristic of prosopagnosia." A more recent study by Etcoff, Freeman, and Cave (1991) challenges this view, concluding instead that configural processing is intact in LH. In the two cases the conclusion is based on visuospatial tests and tasks of perceptual closure (for example, Kaniza figures). Neither of these two studies provides data from face or object recognition tasks that specifically addressed the issue of intact visual integration in higher-order visual cognition.

A new paradigm for studying the influence of structural encoding of faces is provided by studies that have investigated the effect of a face context on perception and recognition of a face part. These effects can either manifest themselves as superiority effects or as inferiority effects, depending on whether a memory rather than a visual search is required (Mermelstein, Banks, & Prinzmetal, 1979). The face superiority effect refers to the finding that face parts are recognised better in a normal face context than outside it or in a scrambled face (Homa, Haver, & Schwartz, 1976; Van Santen & Jonides, 1978). This effect is similar to the word superiority effect, where letters are recognised better and faster when presented in the context of a real word than that of a pseudoword (Reicher, 1969). The same effect of context was found in a search task with conjunction of features vs. isolated features (Suzuki & Cavanagh, 1995). A similar effect was reported in studies examining the whole face advantage, as improved performance of recognising whole faces vs. face parts was not found with scrambled faces (Tanaka & Farah, 1993). Recently Gauthier and Tarr (1997) and Tanaka and Gauthier (1997) have studied this part/whole advantage for objects other than faces in an effort to pull apart the importance of stimulus configuration (which is either parts-based or referred to as "holistic" in the sense of Farah and collaborators) and that of expertise with the stimulus domain. These studies provided evidence for holistic processing of cars, houses, cells, and "greebles".

There are two aspects to structural encoding of faces that are central to our experiments. Since face superiority does not occur when the face configuration is lost because the face parts are scrambled (Mermelstein et al., 1976), the effect is related to presence of the normal face *configuration*. Moreover, since the effect disappears or is strongly reduced when a normally configured face is inverted, the face context effect also depends on *canonical orientation*. A reversed effect of that found in normals would be consistent with the previous reports of inversion superiority. If, moreover, the contrast between normal and scrambled faces also yields the reverse pattern of that found in normals, we have significantly expanded the scope of the previous findings and thereby pointed to structural encoding as the common factor explaining inversion superiority as well as context inferiority.

The goal of Experiment 1 is to see whether structural encoding of the face overrules LH's part-based strategies. If LH's performance still reflects inversion superiority, this would testify to the strong dominance of structural encoding, more specifically the role of canonical orientation. We then need to test, with a new paradigm based on the face context effect, whether his spared structural encoding still dominates explicitly induced internal part-based processes (Experiment 3). Experiment 2 was run with normal subjects in order to establish that the pattern of results typical for the face context effect obtains with our novel materials and testing procedure. These results are also useful as control data for LH.

Case Presentation

Prosopagnosic patient LH is a 48-year-old minister and social worker, who suffered a severe closed head injury in an automobile accident at the age of 18. What follows is a brief summary of the aspects relevant for the present study, since the case has been reported in the literature on previous occasions beginning with Teuber (1968). LH has bilateral lesions affecting visual association cortices and the subjacent white matter. These sites include the right temporal lobe, the left subcortical occipitotemporal white matter, and bilateral parieto-occipital regions (see Levine, Calvanio, & Wolfe, 1980; Levine, Warach, & Farah, 1985, for details of visual testing). Spatial perception was untouched by his injuries. LH performed flawlessly on a standard test of judging the orientation of lines (Benton, Hamsher, Varney, & Spreen, 1978). He has no discernible language deficits. Writing is normal but reading is slow. Copying of objects and complex drawings is excellent. LH was 85% accurate on the object decision task, judging 87% of the objects as real and only 11% of the nonobjects as real (Etcoff et al., 1991).

LH's most striking deficit concerns faces. He is unable to recognise any familiar face. Recognition of individuals via other channels such as their voices remains intact, as does his retention of biographical information. LH scored 36/54 on the Benton-Van Allen face matching task (Benton & van Allen, 1968), a result that qualifies as impaired. On matching of identical faces he was 100% accurate, but when test and target differed on lighting and appeared fragmented and silhouetted he scored only 54% correct.

EXPERIMENT 1. DOES INVERSION SUPERIORITY GENERALISE TO NONHUMAN FACES?

Animal faces present stimuli that share the basic configuration and orientation with human faces but differ in the internal and external face parts (eyes, mouth, but also hair, ears, shape of head, etc). Prosopagnosia extends sometimes to nonhuman faces for which the patient previously had a particular expertise (Bornstein, Sroka, & Munitz, 1969). Sometimes prosopagnosics regain animal face recognition while human face recognition remains impaired (Bruyer, et al., 1983; McNeil & Warrington, 1993). Prior to his accident LH had no particular expertise with animals, nor was he particularly knowledgeable about a specific species. We reasoned that using animal faces would enhance the use of part-based strategies. If so, his performance would be the same for upright as for inverted stimuli. We chose a task that consisted of normal human faces (man, woman) as well as animal faces (cow, monkey) and images generated by blending these in order to obtain a stimulus continuum, enabling us to use a task of categorical perception. From the literature on categorical perception it is well known that the more subjects are acquainted with the stimuli the more their perception is driven by the underlying categories rather than by peripheral stimulus aspects (Repp, 1984). The stimuli were presented to normal subjects in an earlier study (Campbell, Pascalis, Coleman, Wallace, & Benson, 1997). Campbell et al. found a normal inversion effect in a two-alternative forced-choice matching task (2AFC), although normals could still identify inverted stimuli as belonging to a specific category. If overall similarity in configuration between human and animal faces determines the course of processing then LH might not be able to take advantage of the very obvious differences between parts of the face that easily allow discrimination between a pair of adjacent stimuli. In that case LH would show inversion superiority for animal and human faces alike.

Materials and Procedure

Two sets of 15 pictures each were obtained as follows. Starting from 3 natural photographs (a female face, a monkey face, and a cow face for the first series and a male face, a monkey face, and a cow face for the second series), 12 intermediate stimuli were created with a morphing program (see Campbell et al., 1997, for details). The morphing went through four intermediate steps from one kind of face into the other (from male or female face to monkey face and to cow face). Within each series, pairs of adjacent stimuli were probes in a 2AFC task, with either the one or the other as the target. This resulted in 30 trials, each with a different probe. For testing LH, laser prints of the computer images were used. The probe was shown for 4sec, followed by the two alternatives. LH responded by pointing to the left or the right picture. In a separate testing session, these same probes were used in an identification task. LH made a forced choice between one of the three stimuli categories.

Results

Performance on this task was 60% (18/30) correct choices (see Table 1), which does not differ reliably from chance performance ($\chi^2 = 0.61$, $P > .25$). In a separate testing session some weeks later the same stimuli were presented upside-down. LH was 83% (25/30) correct on this test, which is reliably better than chance performance ($\chi^2 = 7.5$, $P < .01$) and superior to the performance on the normally oriented stimuli ($\chi^2 = 4.02$, $P < .05$). Given the limited number of trials for the unmodified stimuli, a comparison between the three face categories could not be made. Interestingly, on trials using stimuli exactly in between categories (40%–60% of the two anchor points), inverting the stimuli yielded the most improvement in performance (from 5/9, 44% error to 0% error).

In the forced-choice identification task, we analysed trials with the normal human, cow, or monkey images only (57%). LH performed at ceiling with the human faces (100%), reasonably well (71%) with the cow faces, and at chance (30%) with the monkey faces. His bad performance with the monkey faces was due to consistently classifying these faces as human. However, the cow faces were mistakenly classified as monkey faces.

Table 1. *Patient LH's Percentage Correct on a Simultaneous Matching Task With Animal Faces*

	Upright	*Inverted*
% correct	60	83

More accurate on inverted than upright: $\chi^2 = 4.02$, $P < .05$.

Discussion

The question raised in Experiment 1 was whether LH would show better performance with inverted presentation (inversion superiority) for human as well as for animal faces. The animal faces have the same schematic configuration as human faces but are more discriminable because of numerous internal and external details. Using the blended stimuli should encourage parts-based processing in LH. However, the data show that LH performs at chance level with all upright stimuli but he is clearly much better when the faces are presented upside-down. This generalised face inversion superiority effect suggests that structural encoding of the face overrules the ability to attend to the local details, which is so clearly manifest in LH's performance with upside-down faces. Various aspects of this result require comment.

The first thing worth noting is that this result confirms the inversion superiority for human faces previously observed for LH (Farah et al., 1995) and AD (de Gelder et al., 1998). The finding also adds to evidence in favour of theories arguing that upright and inverted faces are dealt with by separate mechanisms, also called dual-route models (Moscovitch et al., 1997). The fact that LH's performance shows the same pattern whether the faces are animal or human suggests that the critical factor is the structural encoding of the face and not expertise with the stimulus class. Animal faces have only a schematic configuration in common with human faces and differ from each other and from human faces in many local details. The presence of this configuration in its normal orientation appears to be enough to interfere with the application of parts-based strategies to the upright stimuli. Our results are consistent with the findings by Gauthier et al. (1997) and Tanaka and Gauthier (1998), showing that expertise with the stimulus category is not a significant factor in determining holistic encoding. Although our notion of structural encoding is weaker, the findings clearly converge.

The present result cannot be explained by referring to loss of the ability to perceive second-order configuration, characteristic of prosopagnosic patients. Undoubtedly LH, like other prosopagnosic patients, has lost the use of second-order configuration information or the typical ability to tell apart individual faces, and his chance performance with upright faces confirms that once more. But the crucial aspect of our results is the relationship between poor performance with upright and good performance with inverted stimuli. This pattern cannot be explained by reference to loss of the ability to use second-order information nor by reference to intact parts-based strategies. Neither of these explanations can account for the difference in performance between the upright and the inverted condition, since both these explanations suggest that upright and inverted faces are dealt with in the same fashion. Instead, these results testify to the influence on later processes of LH's spared ability of structural encoding. As we noted in the Introduction, we have adopted the notion of structural encoding to refer to the perceptual stage of encoding the face structure but cannot at this stage favour a view that structural encoding is entirely the same as making a category decision, or that it either precedes, parallels, or follows upon it.

The next experiment with LH (Experiment 3) looks into the influence of structural encoding more closely. It used a new paradigm, that of the face context effect, which requires whole-based and parts-based matching processes. This paradigm allows us to look at the effect of orientation (like Experiment 1) but also to study the impact of the configuration by comparing normal and scrambled faces. Also, the stimulus set could be controlled such that any difference between one face and another was strictly limited to either the eyes or the mouth.

EXPERIMENT 2. INNER FACIAL FEATURES: FACE CONTEXT EFFECTS FOR MATCHING FULL FACES AND PARTS-BASED MATCHING IN NORMALS

Experiments 2 and 3 are designed to study directly whether structural encoding of faces is intact, by using the face inversion effect and the face superiority effect with new materials and a new task. A set of face materials was constructed, each one based on the same natural-looking facial contour. Thus, in contrast with Experiment 1, stimuli did not provide any external cues and attention was focused entirely on the inner face parts. These stimuli should encourage featural processing as they can be differentiated only by close examination of the eyes or the mouth (see Appendix A for an example). Two tasks were designed: matching of whole faces and matching of an isolated face part to its corresponding face part presented in a whole-face context. Both tasks are presented in a simultaneous matching paradigm with three conditions: upright, scrambled, and inverted. The comparison of upright and scrambled performance is relevant for understanding the role of configuration, and comparing upright vs. inverted presentation also informs about the role of canonical orientation. A simultaneous matching task was chosen in order to focus on structural encoding as it takes place in perception. To further encourage parts-based comparison based on visual search, a 2AFC task was preferred over a same/different decision.

Experiment 2 presented these tasks to normal subjects and was performed because of the novelty of the tasks and of the materials.

Subjects

Twenty students from Tilburg University participated as subjects in two simultaneous matching tasks.

Materials

A black-and-white computer-edited prototype face of photographic quality of a young male served as the framework. One of a set of six pairs of eyes and six mouths were put in this facial contour, making for six different faces. These faces could be presented upright or inverted. A face presentation covered approximately 2° of visual angle. Further, an equal number of scrambled faces was made by interchanging the position of eyes and mouth. Thus, there are three conditions: inverted, normal, and scrambled faces.

Method and Results

Order of the two tasks and the two blocks (normal-inverted-scrambled, or scrambled-inverted-normal) was balanced between subjects. In between the two tasks subjects were given another task with different stimuli, which lasted for about 15 minutes.

Experiment 2A: Matching Full Faces

For each condition (upright, inverted, and scrambled) 60 face pairs were made: 30 "different" and 30 "same." Each subject was presented with all conditions. Presentation was blocked and a block consisted of 18 "same" and 18 "different" trials, presented in random order. A trial started with a fixation cross for 500msec. Then two whole faces were presented simultaneously until a response was made.

As expected with unconstrained viewing time, subjects' performance was almost flawless. However, the pattern of latencies for the different conditions is revealing. In task 1 (whole-to-whole matching), there was an overall effect of presentation [$F(2,18) = 18.13$, $P < .001$]. The normal presented faces were responded to faster than either the scrambled faces [$F(1,19) = 40.04$, $P < .001$] or the inverted faces [$F(1,19) = 13.54$, $P < .002$]. Separate anaylsis revealed that the normal presentation advantage was significant for both the "same" trials [$F(2,18) = 9.11$, $P < .002$] and the "different" trials [$F(2,18) = 23.79$, $P < .001$].

Experiment 2B: Matching Face Parts to the Corresponding Part in Full Faces

The same subjects performed a simultaneous matching task, this time involving faces and facial parts. Stimuli were the same whole faces and face parts (six eyes and six mouths). There were three blocks of trials corresponding to three presentation conditions: upright, inverted, and scrambled. Each subject was presented with each of 108 trials: 18 eye and 18 mouth trials for each presentation block. A trial consisted of a fixation cross for 800msec, followed by a simultaneous presentation of a whole face at the top and two parts at the bottom of the screen. Subjects indicated by a key press which of the two parts (left or right) was present in the whole face.

Again, errors were too few to reveal any effects in accuracy. Latencies showed a main effect of Eye-mouth [$F(1,19) = 16.15$, $P = .001$] and an Eye-mouth × Presentation interaction [$F(2,38) = 3.8$, $P = .021$], but no main effect of Orientation. Accordingly, the difference in response times between normal and inverted, or normal and scrambled, faces is not significant (see Table 2).

Discussion

The results of Experiment 2A show that in this novel design with normal subjects, using a simultaneous matching task, performance with normal faces is clearly superior to that with inverted or scrambled faces. Thus, both the face superiority and the face inversion effect obtain with these materials and are found even with unlimited viewing time. These results further show that with stimuli differing from each other exclusively in the internal parts of the face, there was still an effect of face configuration even if both the stimulus properties and the simultaneous matching presentation could have induced visual search for the critical part. In that case the difference between the upright condition would have disappeared and latencies would have been the same for the three conditions. This is exactly what happened in Experiment 2B, where the context effect is no longer observed.

The pattern of an advantage of matching normal whole faces over scrambled faces in the whole-face matching task but not in the parts matching task is consistent with the results of Davidoff and Donnelly (1990) and Farah et al. (1998). The former authors found an object (faces and chairs) superiority effect for whole but not part probes, unless the presentation times were very short. This is consistent with our findings, which indicate that in the parts matching task but not in the whole faces matching task some kind of featural or parts-based analysis was used. The fact that an attentional manipulation can overrule face superiority is consistent with the results of an fMRI study on the effect of attention on the activation of the face area in the brain (Wojciulik, Kanwisher, & Driver, 1998).

Table 2. *Normal RTs and Percentage Correct at Simultaneous Matching of Upright, Scrambled, or Inverted Faces with Whole Faces (Experiment 2A) or With Face Parts (Experiment 2B)*

	Upright	*Scrambled*	*Inverted*
Whole–whole			
Mean RT(msec)	1393	1623*	1621**
% correct	97.8	96.9	85.6
Whole–parts			
Mean RT(msec)	1785	1782	1869
% correct	98.3	98.1	96.7

Faster response to upright faces: * $P < .002$; ** $P < .001$.

EXPERIMENT 3. INNER FACIAL FEATURES: FACE SUPERIORITY FOR WHOLE FACE AND PART TO WHOLE MATCHING IN PATIENT LH

LH was presented with the same two tasks as normals (see Experiment 2). Experiment 3 asks whether his ability to focus on stimulus parts will reduce influence of the face configuration observed in Experiment 1. If so, he would not show the face superiority effect of normal subjects in Experiment 2A and he should be able to overcome the effect of configuration and orientation if the task demands explicitly require this (Experiment 2B).

Experiment 3A: Method and Results

Stimuli were the same faces, differing only in internal features, as described in Experiment 2. Laser prints of the stimuli were used for presentation with LH. In the first task, two whole faces were presented. A stimulus pair was shown for as long as it took LH to given an answer (same or different judgement). Instructions were explained by two examples of each condition. Presentation was blocked with sets containing 18 normal, scrambled, or inverted faces. There was a total of 12 blocks alternating, divided over 2 presentation sessions with some weeks in between.

Performance with upright faces did not differ significantly from chance: 31/72 (43.1%). Performance improved in the scrambled face condition: 49/72, 68.1%, both compared with upright presentation ($\chi^2 = 8.14$, $P < .005$) and from chance ($\chi^2 = 4.84$, $P < .05$). Performance on inverted faces was good: 62/72 (86.1%), much better than chance performance ($\chi^2 = 21.6$, $P < .001$) and upright presentation performance ($\chi^2 = 27.32$, $P < .001$).

Experiment 3B: Method and Results

In a separate testing sessions the same task as Experiment 2B was presented. Performance with upright faces was at chance 18/48 (37.5%). Performance in the scrambled condition 32/48 (66.7%) improved from upright ($\chi^2 = 7.06$, $P < .01$), but was just slightly better than chance ($\chi^2 = 2.74$, $P < .1$). Presenting the faces inverted strikingly improved performance (38/48, 79.1%), differing both from chance performance ($\chi^2 = 8.92$, $P < .005$) and from upright performance ($\chi^2 = 15.46$, $P < .001$) (see Table 3).

Discussion

Unlike normal subjects, LH does not benefit from the normal upright presentation to match faces faster than is done in either the scrambled or the inverted condition. His pattern of results is thus the opposite of the face superiority shown by normals (Experiment 2A) and amounts to a face *inferiority* effect. In Experiment 3A, performance with upright faces was at chance, a result that confirms that LH has lost normal processing of faces and cannot rely on a compensation strategy of attending to a specific face part. The comparison of upright and inverted faces shows that LH is very good at matching inverted faces. This aspect of the results confirms that the normal inversion effect is replaced by inversion superiority and replicates previous observations (de Gelder, 1999; de Gelder et al., 1998; Farah et al., 1995) and Experiment 1 of the present study.

Table 3. *Patient LH Percentage Correct on Simultaneous Matching of Upright, Scrambled, or Inverted Faces with Whole Faces (Experiment 3A) or With Face Parts (Experiment 3B)*

% Correct	*Upright*	*Scrambled*	*Inverted*
Whole–whole	43.1	68.1**	86.1***
Whole–parts	37.5	66.7*	79.1***

Scores are significantly improved in scrambled or inverted condition compared with upright condition: *$P < .01$; **$P < .005$; ***$P < .001$.

The results of Experiment 3 consolidate and extend the original finding in significant ways. The present inversion superiority is obtained with face stimuli that differ only in internal parts. Loss of face processing due to prosopagnosia is thus not a consequence of a shift in the reliance on external vs. internal cues or reliance on external cues to the detriment of internal ones. Such a pattern was observed with normal older subjects. These subjects showed the same inversion superiority as reported there but, when tested with stimuli that differed only in internal face parts, the normal pattern of better performance with upright than with inverted faces reappeared. Loss of face skills as a consequence of normal ageing is thus different from its manifestation in prosopagnosia (de Gelder, Rossion, & Pourtois, 1998). Next, the original face superiority result was not simply due to noncanonical orientation of the stimuli. Disturbing the face context by scrambling the parts raised LH's performance considerably and indicates that the presence of the critical face structure is what triggers that interference on parts-based matching.

In Experiment 3B LH again performs very poorly when having to match a part of a face to the corresponding part in a full upright face. For LH, unlike for normal subjects, the facial context continues to influence part recognition even though it is noninformative in the task. Only when the face configuration is lost as a consequence of scrambling or the canonical orientation is lost due to inversion is structural encoding no longer triggered, and LH can make efficient use of his skills in matching parts.

This result is in line with the goals of a previous study using the face superiority effect to ascertain residual intact face processing in prosopagnosics (Davidoff & Donnelly, 1990), but the outcome with LH is different. The authors correctly note that if prosopagnosia were a disorder specific only for recognition of familiar faces, prosopagnosics would show a normal face superiority effect. Instead, their patient KD does not show face superiority and thus proves their point that some prosopagnosics have problems with structural encoding and cannot achieve an integrated representation of a face stimulus (compromising subsequent processes of identity recognition). In contrast, LH's inversion superiority and face inferiority is evidence that his problems do not have their origin in a difficulty with achieving an integrated face representation. With respect to that issue, the present study shows that having intact structural encoding of faces is not sufficient for subsequent personal identity recognition and may actually constitute an obstacle for alternative compensation strategies.

GENERAL DISCUSSION

The influence of spared structural encoding of faces in a prosopagnosic patient is examined using the inversion effect and the face context effect. Starting from the inversion superiority previously reported, the study asked how the deficit in individual face recognition is related to two perceptual abilities that are spared in this patient but between which there is interference when both are applied to the face stimulus: structural encoding of the face and parts-based matching procedures. Three experiments studied this relationship with task demands and stimulus properties designed to trigger the parts-based processes. In Experiment 1, human and animal faces are presented upright or inverted, with good performance only for inverted condition. In Experiment 2 normals show a clear face context effect (matching of upright faces is easier than matching scrambled or inverted ones) in the full face matching task, whereas in the parts matching task the face superiority effect disappears. In contrast, LH shows a face inferiority effect when matching full faces and when matching an isolated face part to a part in a full face context. The results show that structural encoding of the face overrules parts-based procedures that could otherwise be helpful to tell individual faces apart. Our experiments show that even when task demands and stimulus properties are designed to boost an alternative routine this is overruled by spared structural encoding of the face. Paradoxically, the degree of face impairment of prosopagnosic patients thus seems to predict the extent to which compensation strategies can be successful. In the case of LH, spared structural encoding does lead to worse performance by inhibiting parts-based procedures. Our results stress the need to examine in detail the initial stages on which subsequent personal identity recognition depends. This perceptual stage of structural encoding may be impaired, as for example in the patients reported by Davidoff and Landis (1990), or it may be intact as for LH.

The notion of spared structural encoding as the locus of inhibition was already hinted at by McNeil and Warrington (1993) at the end of their study of WJ. This patient is severely prosopagnosic and has not recovered any recognition of human faces. Nevertheless, he is perfectly able to recognise the faces of his sheep and he can tell apart different unfamiliar examples in a recognition memory task. The authors note that apparently WJ does not seem able to use the strategies he employs with sheep to compensate for his deficit with human faces. They go on to make two important suggestions. First, WJ's deficit might consist of a disconnection between the structural encoding stage and the face recognition nodes of the Bruce and Young model. Second, they suggest that this deficit might "prevent the development of alternative methods of perceptual encoding" (McNeil & Warrington, 1993, p.9). This suggestion of an interference from intact processes is supported by the present results.

In this study we have not looked at inversion superiority for objects. Our previous results with both LH and AD provide evidence that inversion superiority also obtains in these two patients for matching of objects. As we argued previously, this implies that structural encoding is critical not only for faces but also for some object categories. Our finding of an inversion superiority for some nonface stimuli is actually consistent with the recent report by Farah, Wilson, Drain, and Tanaka (1998). These authors now propose what in fact amounts to a relative version of their original claims about face specificity, whereby the inversion effect is *relatively* strongest for faces and faces are processed *relatively* more holistically than other objects.

Our findings have implications for what the theories of face processing we reviewed suggest to be the critical loss in prosopagnosia. The pattern of lost vs. spared processing routines does not correspond to the conventional view that whatever is face-specific is lost and whatever is object-specific is spared. Neither does our study support the view that first-order abilities are spared and second-order ones (in the sense of Carey and collaborators) lost. Moreover, it suggests that first- and second-order information is not independent. On the other hand, Farah's notion of a damaged face module (Farah et al., 1995) is not entirely satisfactory because it does not provide room for sorting out what is lost and what could be spared for an inhibitory role of spared structural encoding. Our results add to the evidence provided by Moscovitch et al. (1997), showing that a sharp division between face-specific or whole-based procedures and object-specific or parts-based procedures is not entirely satisfactory. Our results with LH make a point similar to theirs in a different way, by showing an influence of whole-based on parts-based routines which results in an inhibition of the latter by the former.

Inversion superiority has only been reported in a couple of patients so far. Given the number of case studies available and the widespread view that these patients can still see faces as a separate visual category, this is surprising. A question for future research is to understand why only some prosopagnosic patients seem to show this phenomenon (de Gelder, Rouw, & Rossion, 1999). A critical factor may be the extent of preserved face processing abilities in prosopagnosics. The two patients for whom we have now reported inversion superiority do not suffer from the kind of agnosia that has been labeled integrative agnosia (Humphreys & Riddock, 1987), where the patient manages the see parts of an object but fails to integrate them into a whole. Our conjecture is that in such patients inversion superiority will not be observed. However, it is worth noting that only a few studies of prosopagnosics have addressed this issue with the use of experimental tasks that are more demanding than clinical batteries. How strong is the evidence for intact face decisions in prosopagnosia and what conclusions about spared skills does it warrant? In conventional screening of face problems, a face recognition battery like the Warrington Face Recognition Test (relying heavily on memory for faces) or the face test by Benton and van Allen (1968) or a face decision task are used (for instance, Schweich & Bruyer, 1993). If it is indeed the case that prosopagnosics can make intact category assignments for faces, they should perform at ceiling on a face decision task. But as shown in the last study, out of nine prosopagnosic patients only three performed like controls, two were borderline, and the remaining four failed to tell faces from nonfaces. The question can still be raised as to what the performance of the three good subjects tells about structural encoding? Davidoff and Landis (1990) argued convincingly that evidence from performance on the Benton test or on a face decision task is not sufficiently convincing to establish intact structural encoding. Usually in a face decision task the stimuli (normal, scrambled, incomplete faces) are presented under unconstrained viewing conditions, which allows for maximal contribution from general problem-solving strategies. Patients can combine intact spatial knowledge of the canonical face format and apply general visual strategies based on features, as in object recognition. It is thus entirely possible to arrive at a correct facial decision without encoding the facial structure in the course of perception. From this vantage point, an important question for future research is whether prosopagnosics can make face decisions based on structural encoding in the course of perception, as contrasted with being able to use it off-line in order to make explicit, consious decisions about stimulus category.

Finally, more detailed information is needed about the specific loci of, on the one hand, the patient's lesions and, on the other, areas involved in treating upright vs. inverted faces and other objects in normal subjects (Kanwisher, Tong, & Nakayama, 1998). But we cannot exclude at present that inversion superiority for faces in prosopagnosia results from a more complex combination of spared and lost abilities.

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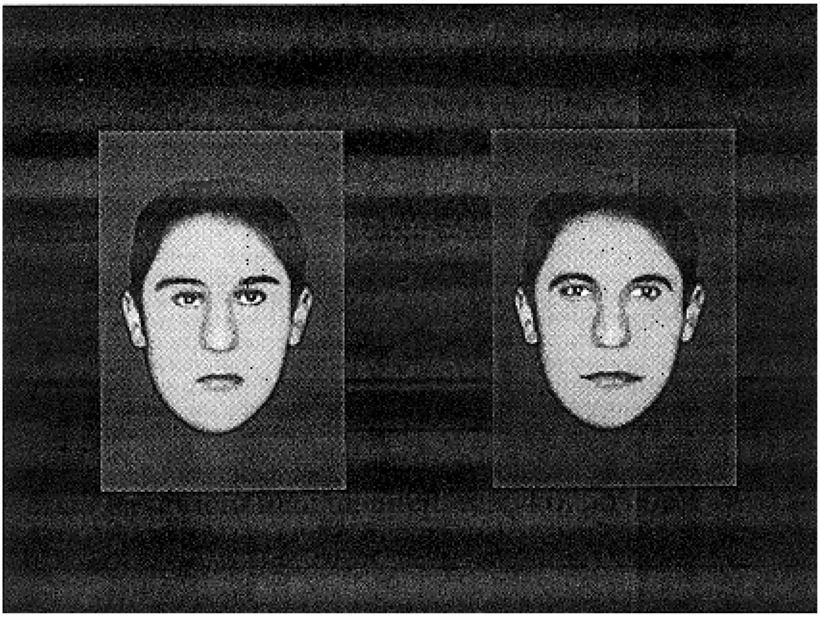
APPENDIX A

Experiment 2A and 3A: Matching Whole Faces



Experiment 2B and 3B: Matching Whole Faces to Face Parts