

FACIAL NEGLECT

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Abstract—Following a stroke, a retired industrial chemist, K.L., complained that faces looked “different” and had become difficult to recognize. Investigation of this problem revealed that it particularly affected the left half of a face as seen by K.L. Defective recognition of this (left) half was found for normal faces, chimaeric faces, and for half-faces presented in isolation, whether upright or inverted. The problem was apparent for both internal and external facial features. Further studies with chimaeric faces demonstrated inattention to left-side features in K.L.’s judgements of facial expression and of resemblance between faces. Moreover, the left-half of a chimaeric face was affected even when it was itself forming part of the face positioned on the right in a display of two horizontally aligned chimaerics. K.L.’s spatial contrast sensitivity function was within normal limits for his age. He did not experience differential difficulty in recognizing the left side of everyday objects or of car-fronts (another stimulus class demanding within-category discrimination between visually similar items that display approximate left–right symmetry). He was also able to sort left or right half-stimuli correctly into the categories “human face”, “dog face”, or “tree”. Although K.L. had a left visual field defect, the problem with faces occurred within otherwise intact parts of his field of vision. We suggest that his disorder can be considered a domain-specific form of unilateral neglect.

INTRODUCTION

A NUMBER of different types of face processing impairment caused by cerebral injury have been reported. These include impairments affecting the recognition of familiar faces [13, 18, 19, 30, 45], name retrieval [25], matching photographs of unfamiliar faces [20, 43], ability to remember new faces [50], ability to interpret facial expressions [36, 37], and lip-reading [14].

The investigation of neuropsychological impairments has been of central importance to the development of theoretical models intended to describe the functional organization of the face processing system [9, 12, 24, 29]. An adequate model should be able to account for the types of breakdown that can occur [21, 56], and there has been an impressive convergence of findings from neuropsychological and neurophysiological investigations and studies of normal subjects [17, 18, 54].

There are, however, types of face processing impairment that have not yet been systematically investigated, and that may also prove to be important in understanding face processing. In the present paper we report a detailed investigation of a patient suffering one such type of impairment, which we will demonstrate is best considered a domain-specific

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form of unilateral neglect. There are no previous reports of this problem in the literature (though there have been one or two hints, which we will discuss later), and the case has implications for understanding both face processing and unilateral neglect.

CASE DESCRIPTION

K.L. was a right-handed former chemical engineer, born in 1920, with a history of arterial disease and transient ischaemic attacks (TIAs), who complained of visual difficulties following a stroke. CT scan in June 1984 showed an infarct in the pole of the right occipital lobe, and a right carotid angiogram showed complete occlusion of the internal carotid artery. On Topcon perimetry, an absolute left lower homonymous quadrantic visual field defect was noted in April 1984, which had increased to left homonymous hemianopia, with macular involvement, by December 1984. Visual acuity was 6/7.5 or better with either eye. Spatial contrast sensitivity functions were generally in the normal range for either eye, with only a slight loss of high spatial frequencies (> 10.10 cycles/degree) for the left eye. The right eye contrast sensitivity function was perfectly normal.

K.L. was referred to us in September 1984, because of his difficulties in recognizing people. His spontaneous complaint was that faces looked "different", and that the eyes in particular seemed to be misplaced. Even his wife looked different, though he added that he was beginning to get used to this. K.L. said that faces did not look blurred (and this claim is consistent with his well-preserved contrast sensitivity function), but reported that he was relying a lot on context or voices to recognize familiar people.

Although faces were the main focus of spontaneous complaint, it was clear from careful questioning that there were some other problems. When K.L. watched snooker on the television, for instance, the balls did not seem to move in straight lines, and he had to check with his wife whether or not the set was faulty. He had been experiencing some distortions at the left edge of his visual field, involving fuzziness "like looking through bottled glass", but these were beginning to wear off. He claimed that he could see clearly despite the bottled-glass effect, which was more akin to a film placed between his eyes and whatever he was looking at, and was in any case confined to the edge of his vision, apparently bordering the hemianopic area. Whatever the origin of this complaint, it seemed to be unrelated to the problem with faces, because when he moved his eyes the fuzziness moved with them, but faces would still look "deformed" in the non-fuzzy parts of the visual field.

Initial neuropsychological assessment

Examinations in October and December 1984 showed no evidence of generalized intellectual deterioration (WAIS verbal IQ: 116), although K.L.'s nonverbal abilities were lower than expected on the basis of his professional background (WAIS performance IQ 99). No abnormalities were apparent in the production and comprehension of speech, and on formal testing his language functions were all in the average to superior range (Chapman reading test: total time: 2 mins 23 sec, 0 errors; spelling: oral: 9.12, written: 11/12; oral fluency (60 sec): objects: 30, animals: 17, "S": 16; Oldfield-Wingfield object naming test: 34/36). Verbal memory (both short and long-term) was unimpaired (WAIS Digit span: age scaled score: 10; Wechsler Memory Scale I Story recall: immediate: 12.5 and 10.5, delayed (60 min): 10 and 9.5). Short-term visual memory was also normal (Benton visual retention test: 23/32), but long-term visual memory was severely impaired (Rey-Osterrieth complex geometrical figure (A): copy: 35.36, delayed (45 min): 5.5/36).

Visual and spatial perception was assessed in further detail, and because some of the tasks used are less well established clinical measures, control data from age-matched normal subjects will be presented in square brackets where necessary. K.L. was slow and hesitant on a task where a symmetrical area had to be detected in a black and white dot pattern (Frith patterns: score: 6 [control mean: 7.7; SD: 1.6]; mean time: 48.4 sec [control mean: 17.2 sec, SD: 9.5 sec]). Some colour perception deficiency was indicated by his performance on the Farnsworth-Munsell sorting task (left eye: error score: 192; right eye: error score: 170 [upper limit of the 95th percentile for his age group; error score: 174]). In contrast, K.L. was able to read small print (Keeler Instruments reading acuity test: N5 corrected) and to match the orientation of line segments (Benton line orientation test: score: 60 [control mean: 57.1, SD: 3.3]; mean time: 8.3 sec [control mean: 6.1 sec, SD: 2.5 sec]). He could perceive the three-dimensional structure in a line drawing of a block construction (Pittsburgh block counting: score: 27 [control mean: 28.9, SD: 6.3]), but mental rotation of two and three-dimensional stimuli posed severe problems (Thurstone flags: score: 22 [control mean: 51.7, SD: 14.2]; Shepard rotation: score: 4 [control mean: 14.7, SD: 5.1]). Two maze tasks were given to K.L., and his performance indicated substantial difficulties in this respect (Elithorn's perceptual maze: score: 8 [control mean: 11.1, SD: 1.5] and Porteus maze: mean errors: 3.25 [control mean: 0.9, SD: 0.7]; mean time: 203 sec [control mean: 98.0 sec, SD: 36.9 sec]).

No evidence of unilateral neglect was detected on two separate item-cancellation tasks [1, 31] and a reading task [22, 34].

Visual object recognition as measured by the Oldfield-Wingfield object naming task was intact (34/36). There was additional evidence for relatively well-preserved recognition of objects: K.L.'s prompt and succinct description of representational line drawings (Binet telegraph boy; Bobertag picture), and correct identification of missing details

in line drawings (WAIS Picture completion: age scaled score: 11). Naming of exemplars from a category with visually similar items (colour photographs of vegetables) was also unproblematic for K.L. (18/20).

In the realm of face perception and recognition, K.L. was severely impaired. He found it difficult to detect a face in pictures of faces with the shadows rendered in black and the highlights in white (Mooney faces: score: 26/40), and he was slow in deciding whether or not a line drawing represented a properly organized face with the eyes, nose, and mouth in the correct position (mean time: 2.59 sec [control mean: 1.11]). When given an even more stringent version of this task, in which the stimuli were only presented for 2 sec each, he made 5/24 errors on a task which is easy for normal subjects. Whilst carrying out the test he commented on his inability to see the faces "as a whole", and said that he was having to rely on checking whether each separate facial feature was presented in the correct location. Matching photographs of unfamiliar faces on identity proved very difficult for K.L. (Benton facial recognition test: score: 32 [control mean: 44.6, SD: 3.3]; Lancaster unfamiliar face matching test: error score: 12 [control mean: 3.9]). Recognition memory for unfamiliar faces was also found to be poor on a task where he was required to detect the recurring faces in a series with foils which appeared only once (Recurring faces test: score: 41/60 [control mean: 53]). Identification of familiar people by the face was also impaired, although this was by no means completely impossible (famous faces board: score: 10/20; Lancaster line up: highly familiar faces: score: 15 [control mean: 18.9, SD: 1.2]).

When describing slides of faces K.L. sometimes maintained that they looked like "montages" of two different people joined at the vertical midline. For some of these "montages" he felt that one side was familiar but the other side was not, or that the eyes were looking in different directions. None of these slides actually were montages, but K.L. clearly doubted our statements to this effect. When he was asked to fixate at a certain point on the screen and the slides were presented to the right of this point, the "montage" sensation remained unaffected.

In summary, K.L. suffered a number of infarcts to the brain which resulted in a left homonymous hemianopia and a mild impairment of colour perception, but left him with normal visual acuity and contrast sensitivity functions. General intellectual abilities and language functions were at least average, and his memory was selectively impaired only for long-term recall of visual, nonverbal material. There were clear indications of some deficits in visual and spatial processing, but no clinical neglect was detected on formal testing. Most importantly, K.L. was disproportionately impaired on every aspect of face perception and recognition which was tested. His subjective complaints of distorted face perception can not be readily explained by his hemianopia, because many hemianopic patients do not experience any difficulties in this respect, and because changing fixation did not seem to affect the experience of distortion. A more detailed investigation of K.L.'s face processing problems was therefore carried out, which forms the basis for this report.

EXPERIMENTAL STUDIES OF FACE PROCESSING

K.L.'s face processing abilities were investigated in testing sessions which took place on a number of occasions between October 1984 and July 1986. During this period he experienced a number of TIAs, usually involving loss of motor control of his left arm and left leg for around 20 min. However, there was no evidence of any change in his performance on formal face processing tasks, though he maintained that he no longer experienced the visual distortions of which he had initially complained. Even when first seen he had claimed that these were wearing off, or that he was getting used to them. In December 1985, however, K.L. suffered another stroke which caused left hemiplegia and visual neglect in reading and item cancellation tasks. Again, his problems with faces were no different on formal testing after this stroke, but it is important to our interpretation that K.L.'s face problems predated the occurrence of full-blown visual neglect. For this reason, we have provided dates for the occasions on which each test was given, and we will report them in a sequence that is as close to chronological order as possible, subject to the constraints dictated by the need for clear exposition.

For the test results presented thus far, we have made comparisons between K.L.'s performance and that of age-matched controls. The rest of the investigation, however, was largely concerned with differences between the processing of left and right sides of the face by K.L. Hence control data are not necessary. Instead K.L. serves as his own control, since our aim is usually to demonstrate that one side of the face is much more severely affected than the other side.

Face construction (December 1984 and January 1985)

Our investigation began by exploring K.L.'s earlier report that faces looked distorted. He was asked to arrange facial features into a properly organized face; a facial outline, eyes, nose and mouth were drawn onto separate transparent acetate sheets, and K.L. was asked to arrange these into a proper configuration. This was done twice in December 1984, and four times in January 1985, always using different stimuli. K.L.'s constructions were made very slowly, and the finished products were invariably distorted on the left side: examples are shown in Fig. 1.

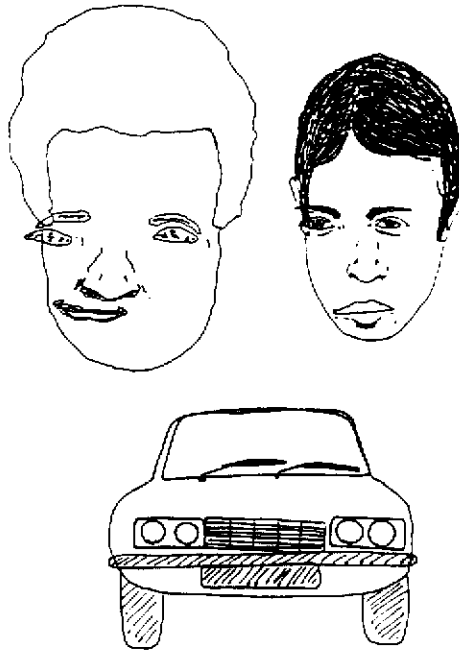


Fig. 1. Examples of face and car constructions made by K.L.

In contrast to these poor face constructions, car fronts were quickly and accurately assembled by K.L. from an equivalent number of components (outline, windscreen, radiator grille, headlights), and showed no sign of left-sided distortion (see Fig. 1).

Identification of chimaeric faces (January 1985)

Chimaeric faces were used to explore the implications of K.L.'s feeling that some of the slides we had shown him were montages. K.L. was first trained to a criterion of 100% correct naming of full-face photographs of 10 well-known people, which had been printed within a circular template in order to obscure much of the background and clothing. These faces were then used to make chimaerics in which the left half of one person's face was joined to the right half of another person's face. An example is shown in Fig. 2. Ten chimaerics were made from correctly printed photographs, and 10 were (intentionally) mirror-reversed. K.L. was asked to name the two half-faces forming each chimaera.

On 19/20 trials K.L. began by naming the half-face falling to his right, and on all trials the half-face falling to his right was quickly and correctly identified. The half-face falling to his

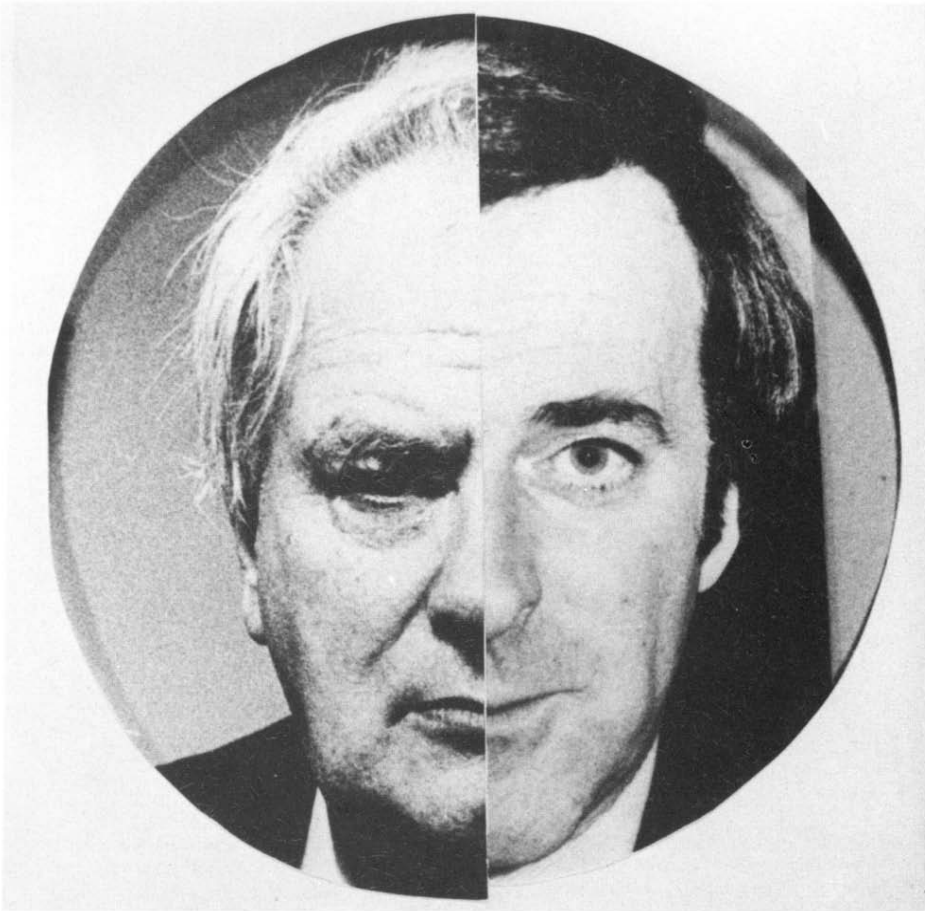


Fig. 2. Example of chimaeric face stimulus used in identification task.

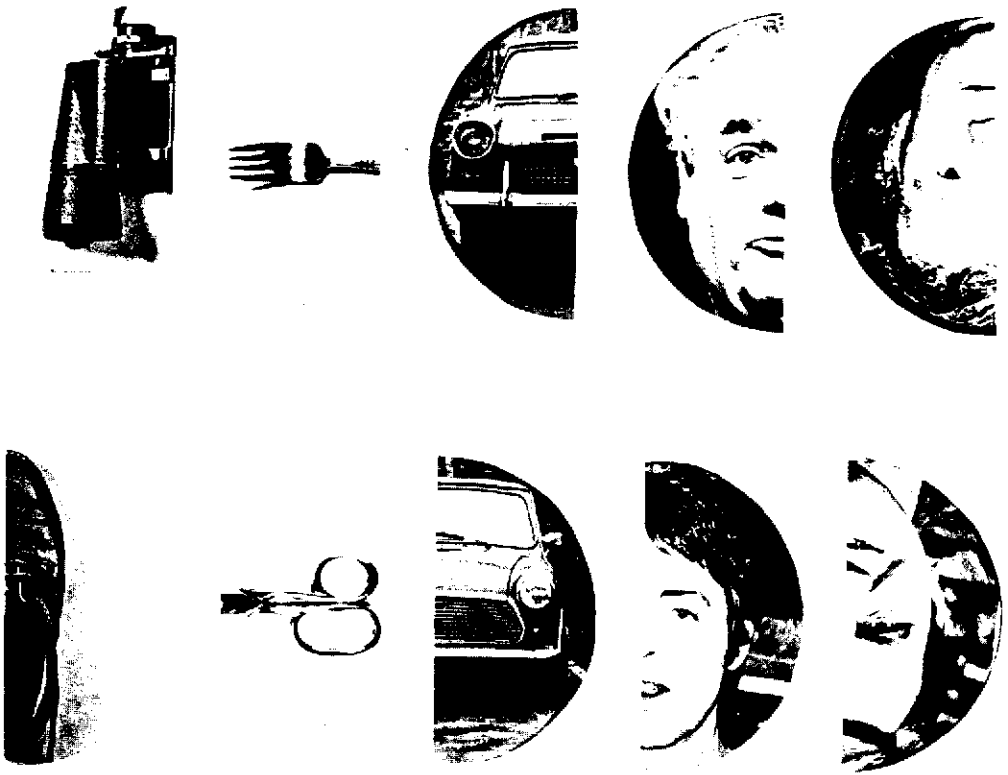


Fig. 3. Examples of half-faces, half-cars, and half-objects used in identification task. Left half-stimuli are shown in the top row, and right half-stimuli in the bottom row. From left to right across the page are examples of symmetric view half-objects, asymmetric view half-objects, half-car-fronts, upright half-faces and inverted half-faces.

left was correctly identified on only 14/20 trials, and in seven of these trials it was only identified after slow and careful examination. Because half the photographs had been printed in mirror-reversed form, we can be certain that this effect relates to the left side of the stimulus *as seen by* K.L., and not to any distortion of his memory for the left or right sides of familiar faces.

Exactly the same types of problem arose when K.L. was instructed to begin by looking to the left of both halves of the chimaera, so that it would fall in his intact right field of vision. On six trials he still made three errors to the left side and none to the right. Two of the three correct left-side responses were preceded by a long pause.

Informal observations suggested that the same problem was also evident for half-faces presented in isolation, and a further test was designed to explore this systematically.

Identification of half-stimuli: faces, cars, objects (April and August 1985)

Photographs of full-face views of 10 famous people were separated at the vertical midline into left and right halves, and the same was done with 10 mirror-reversed prints of the same photographs. The resulting 40 half-faces (20 left, 20 right) were arranged into a pseudo-random order. K.L. was given a short training session in which he was shown the original full-face photographs and then taught the names of the people he did not identify spontaneously. He was then shown the half-faces one at a time, and asked to identify each one. To do this the half-face photographs were placed successively on the table in front of K.L., always in his intact field, so that there was no difference in the positions occupied by left or right half-faces. Reaction times were recorded, and any errors noted.

An equivalent task was made using photographs of 10 car-fronts belonging to vehicles of different makes (badges or writing were blacked out on these photos), and given to K.L. in the same session. He was asked to identify the type of car for each picture. Our rationale was that car-fronts, like faces, are approximately symmetric and demand discrimination between visually similar exemplars for successful recognition.

Further tasks involving object recognition were also given to K.L. For these tasks, the objects were separated into left and right halves along the principal axis of symmetry in one set of photographs (symmetric views), so that the left and right half pictures of each object contained the same features. In the other set of object photographs the objects were separated into left and right halves by cutting at right angles to the principal axis of symmetry (asymmetric views), so that the left and right half pictures of each object contained different features.

Finally, K.L. was also given the face recognition task again, but with all of the stimuli (training and test stimuli) upsidetdown.

Examples of the half-faces, half-cars, and half-objects are shown in Fig. 3. It is essential to bear in mind that in describing these we will use the terms 'left' and 'right' to refer to the side of the stimulus *as seen by* K.L. Thus any particular left half-face would be considered a right half-face when inverted, and so on. This crucial notational point is most easily appreciated from inspection of Fig. 3.

All of these tasks were given to K.L. during a testing session in April 1985, and they were all repeated in a later session in August 1985. Data from both sessions (mean reaction times for correct responses, and error rates) are presented in Table 1.

Table 1 shows that there was no difference in the pattern of K.L.'s responses across the two (April 1985 and August 1985) testing sessions. In both cases there was no differential difficulty of left or right halves for the identification of symmetric view objects, asymmetric view objects, or car-fronts. This absence of differential difficulty for left and right half-cars

Table 1. Mean reaction times (in seconds) for correct responses, and error rates, for identification of left and right half-faces, half-car-fronts, and half-objects by K.L. in testing sessions carried out in April 1985 and August 1985.

	April 1985				August 1985			
	RT (sec)		Errors (max = 20)		RT (sec)		Errors (max = 20)	
	Left half	Right half	Left half	Right half	Left half	Right half	Left half	Right half
Objects								
Symmetric view	1.19	1.44	0	0	1.08	1.29	0	0
Asymmetric view	1.25	1.23	0	0	1.37	1.20	0	0
Car-fronts	2.87	2.42	1	1	2.27	2.63	0	1
Faces								
Upright	8.20	2.87	4	1	8.35	2.73	2	0
Inverted	8.23	5.55	11	7	11.13	4.83	10	6

and half-objects was evident both in the reaction times and for the error rates. In marked contrast, both upright and inverted left half-faces were much more slowly identified than right half-faces, and there were also more errors to left half-faces.

In order to confirm the principal conclusions by formal analysis, two analyses of variance were carried out. Mean reaction times for correct recognition of each of the 10 stimulus faces from upright or inverted left or right halves were submitted to a two-factor analysis of variance to determine the effects of stimulus orientation (upright or inverted; repeated measure) and stimulus side (left half or right half; repeated measure). The main effect of orientation did not reach statistical significance [$F(1, 9) = 2.92, P > 0.1$], but responses to left half-faces were slower than responses to right half-faces [side $F(1, 9) = 23.46, P < 0.01$]. There was no orientation \times side interaction [$F < 1$], indicating that the impairment for identification of left half-faces held for both upright and inverted stimuli.

For the second analysis of variance, mean reaction times for correct recognition of each of the 10 upright faces and 10 car-fronts were analysed to determine the effects of stimulus type (faces or cars) and stimulus side (left half or right half; repeated measure). Main effects of stimulus type [$F(1, 18) = 16.23, P < 0.01$] and stimulus side [$F(1, 18) = 11.60, P < 0.01$] were found, but both these main effects were qualified by a type \times side interaction [$F(1, 18) = 11.02, P < 0.01$]. Tukey tests ($\alpha = 0.05$) were used to analyse this interaction, and showed that reaction times to left half-faces were slower than reaction times to any of the other stimuli (right half-faces, left half-car-fronts, or right half-car-fronts), which did not differ from each other.

Half-face familiarity decision (April and August 1985)

Although the identification task showed a clear impairment for left half-faces, there are a number of different levels at which face naming can break down [9, 24, 29]. A familiarity decision task was thus also run, to try to pinpoint the locus of impairment more precisely. In familiarity decision, the subject has only to decide whether or not a face (or in this case a half-face) is familiar; this is the simplest decision that demands involvement of the recognition system [58].

Full-face photographs of five famous people, and five non-famous people matched to the famous people for age and hairstyle, were used to create left and right half-face stimuli in the

same manner as for the half-face identification task. K.L. was given training on familiarity decision to the full-face photographs, and then tested with 20 upright left half-faces (10 famous, 10 non-famous) and 20 upright right half-faces (10 famous, 10 non-famous) presented in a pseudo-random order. Vocal reaction times for correct responses were recorded, and errors noted. The task was then repeated with all of the stimuli inverted. This entire procedure was carried out during a testing session in April 1985, and repeated in August 1985.

Mean correct reaction times and error rates for each session are shown in Table 2. Again, there was no change in the pattern of K.L.'s performance across sessions. A three-factor

Table 2. Mean reaction times (in seconds) for correct responses, and error rates, for familiarity decision to upright and inverted left and right half-faces by K.L. in testing sessions carried out in April 1985 and August 1985.

	April 1985				August 1985			
	RT (sec)		Errors (max = 20)		RT (sec)		Errors (max = 20)	
	Left half	Right half	Left half	Right half	Left half	Right half	Left half	Right half
Upright	3.01	2.39	3	0	2.63	2.06	4	1
Inverted	5.44	2.78	9	6	8.12	5.73	7	4

analysis of variance of the correct reaction times to each of the stimulus faces was carried out, to determine the effects of stimulus orientation (upright or inverted; repeated measure), stimulus side (left half or right half; repeated measure), and familiarity (famous or non-famous face). There were significant main effects of all three factors, with faster responses to upright than to inverted faces [orientation, $F(1, 8) = 56.82$, $P < 0.001$], to right than to left half-faces [side, $F(1, 8) = 9.28$, $P < 0.05$], and to famous than to non-famous faces [familiarity, $F(1, 8) = 57.80$, $P < 0.001$]. The orientation \times side interaction did not reach statistical significance [$F(1, 8) = 3.37$, $P > 0.1$], indicating that the finding of impaired performance to left half-faces held for upright and for inverted stimuli.

Visual neglect

The above tasks were all completed at a time when K.L. showed no signs of general visual neglect in his everyday behaviour, or in formal reading or item-cancellation tasks. An example of his item-cancellation (in which he was asked to mark the circles on a page of circles and crosses), taken from the April 1985 testing session, is shown in Fig. 4. In the same session, he read a complex passage of text without error, and correctly read a list of 60 words.

After suffering a further stroke in December 1985, however, K.L. did show general visual neglect, both in everyday life (he started bumping into things to his left, or leaving some food on the left of his plate) and in laboratory tasks. His performance of an item-cancellation task given in February 1986 is shown in Fig. 4, and he also neglected the leftmost edge of a page of text when reading, and made five errors involving the beginnings of words in reading a list of 40 words (cluster read as "luster", feast as "east", wailing as "mailing", cream as "dream", bean as "mean"). Because K.L.'s face impairment predated the onset of this visual neglect, and did not seem to be affected by it in any way, we continued to study it. All of the tests we report beyond this point were thus carried out when K.L. also suffered general visual neglect.

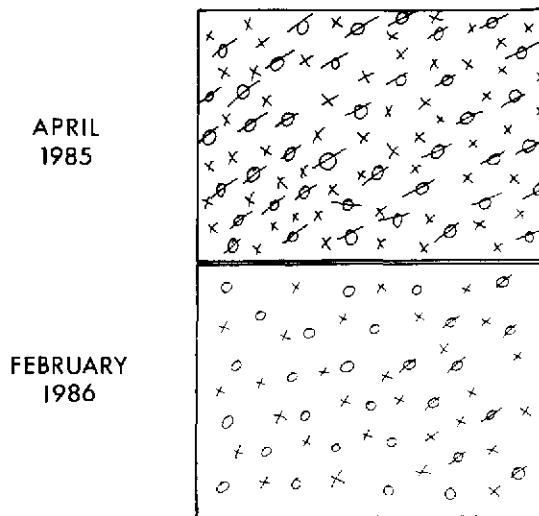


Fig. 4. Performance of item-cancellation tasks (marking the circles in an array of circles and crosses) by K.L. in April 1985 (top) and February 1986 (bottom).

Identification of half-faces without pretraining (February 1986)

In previous identification tasks, K.L. had been trained at recognizing the stimuli involved, in order to make the left-side vs right-side comparison as neat as possible. A potential disadvantage of this technique, however, is that the left-right difference might somehow have arisen from the way in which K.L. learnt the stimuli in the training session. To rule out this possibility, left and right half-face stimuli were made from full-face photographs of 30 famous people who had not been used in previous tasks. The resulting 30 left and 30 right half-faces were arranged into random order and presented to K.L. for identification without any training. He correctly identified 20 right half-faces, but only seven left half-faces ($z = 2.31$, 2-tailed $P < 0.05$), so we can conclude that the left-right difference does not originate in the training procedure. This finding is, of course, consistent with the fact that K.L. had shown problems involving the left side of faces in face construction tasks (see Fig. 1), for which no training procedure had been necessary.

An additional feature of the present task was that the face photographs were printed in a rectangular frame, with the face filling as much of the frame as possible, rather than the circular frame used in previous tasks. This meant that the half-faces were rectangular rather than semicircular in shape, and rules out any influence of this (photograph shape) factor.

Identification of half-faces of personally familiar people (February 1986)

This task was carried out as a check that previous findings were not for some reason restricted to the faces of people known only through the mass-media ('famous' faces). We also took the opportunity to examine which features of the face (internal or external) might contribute to the greater difficulty of left-side identification for K.L.

Full-face photographs were taken of five people known to K.L. (the authors and one other female), photographed against a white background. These were used to create slides of left and right half-faces, left and right internal features (by masking external features), and left or right external features (by masking internal features). Examples are shown in Fig. 5.

As in previous tasks, half the stimuli were mirror-reversed, to control for any asymmetry of

facial features. Twenty left and 20 right trials were then given for half-faces, internal features, and external features. For each condition, K.L. was asked to identify (i.e. name) the person shown. Mean reaction times for correct responses and error rates are given in Table 3.

Again, K.L. had difficulty identifying left-stimuli, both in terms of his correct reaction times and error rates. Thus our previous findings are not restricted to famous faces only. Impaired recognition of the left-side stimuli was found for 'complete' half-faces and for internal and external features, with no sign of any differential involvement of internal or external features in producing the effect.

An analysis of variance was carried out, in order to confirm these conclusions by formal analysis. Mean reaction times for correct recognition of each of the five stimulus faces from left or right half-face, internal features, or external features were submitted to a two-factor analysis of variance to determine the effects of stimulus type (half-face, internal features, or external features; repeated measure) and stimulus side (left or right; repeated measure). The only significant effect was for stimulus side [$F(1, 4) = 10.86, P < 0.05$], with slower responses to left than to right-side stimuli. There was no effect of stimulus type [$F < 1$], and no stimulus type \times stimulus side interaction [$F < 1$].

Identification as a face: left and right half-stimuli (February 1986)

The tasks carried out thus far had consistently shown that *recognition* of left half-faces was severely impaired for K.L. It thus seemed to us important to determine whether he would also show equivalent problems on other face processing tasks that do not demand recognition. An obvious place to begin was with a task which even prosopagnosic patients do not find very difficult [13, 18, 45]; deciding whether or not a stimulus is a human face. This was given to K.L. as a task involving left and right half-stimuli.

Full-face photographs of 10 humans and five dogs, and photographs of five trees, were separated into left and right sides by cutting along the vertical midline. These were presented to K.L. one at a time in random order, and he was asked to decide whether each was a face, dog, or tree. He found this almost trivially easy, made no errors, and achieved overall reaction times of 0.99 sec for classification of left half-stimuli and 1.00 sec for right half-stimuli.

Perception of chimaeric faces

Studies of the perception of chimaeric faces by normal subjects have shown that the side of the chimaera falling to a person's left often exerts a disproportionate influence on the perception of the face. In the light of our previous findings, it seemed most unlikely that this would hold for K.L., and tests were given to explore his perception of expression and identity (resemblance) in chimaeric faces.

Expression (February 1986 and March 1986). The expression perception task was adapted from the work of HELLER and LEVY, and LEVY *et al.* [33, 41]. Ten people (five men, five women) who were unfamiliar to K.L. were photographed in smiling and unsmiling full-face poses. These photographs were cut along the vertical midline and joined together to create chimaerics in which each person appeared with one half of the face smiling, and one half unsmiling. These chimaerics were presented to K.L. one at a time, accompanied by a mirror-reversed version of the same chimaeric. Examples are given in Fig. 6. K.L.'s task was to inspect the faces carefully and choose the one which looked 'happier'.

In February 1986 K.L. was tested with chimaerics presented simultaneously, one above the other, as in Fig. 6(A). On 37/40 trials ($z = 5.22$, 2-tailed $P < 0.001$) he chose as looking

Table 3. Mean reaction times (in seconds) for correct responses, and error rates, for identification of left and right half-faces, internal features, and external features of personally familiar people by K.L. (February 1986)

	RT (sec)		Errors (max = 20)	
	Left half	Right half	Left half	Right half
Half-faces	4.85	2.61	9	2
Internal features	4.20	2.68	10	5
External features	4.08	2.49	10	5

happier the chimaeric in which the side falling to his right was the smiling side. This very marked asymmetry in his choices is in the reverse direction to the more modest asymmetry that would be expected for normal subjects, and confirms that his problem with the left side of seen faces extends to interpreting their expressions.

A further test in March 1986 showed this phenomenon even more strikingly. In this test, the two chimaerics were mounted horizontally alongside each other, as in Fig. 6(B). K.L. still chose as looking happier the chimaeric in which the side falling to his right was the smiling side on 36/40 trials ($z=4.90$, 2-tailed $P<0.001$), even though that often meant that he was choosing the leftmost of the two chimaeric faces (on 17/20 trials in which the rightmost chimaeric contained the smiling right side it was chosen, and on 19/20 trials in which the leftmost chimaeric contained the smiling right side it was chosen). Hence it is clear that K.L.'s problem is linked to the left side of the individual face, rather than to the left side of any display containing faces.

Resemblance (February 1986 and May 1986). A further chimaeric face task, requiring perception of resemblance between chimaerics and an original, was adapted from GILBERT and BAKAN [26] and KOLB *et al.* [35]. Full-face photographs of 10 unfamiliar people (five men, five women) were printed in normal or mirror-reversed form and then cut along the vertical midline. Chimaeric faces were then formed from the left side of one stimulus and its mirror image, or from the right side of the stimulus and its mirror image. The original photographs (including the mirror-reversed ones) were presented to K.L. one at a time, accompanied by the left side + mirror image and the right side + mirror image chimaerics above and below the original. Figure 7 shows an example. K.L. was asked to look carefully at the faces and decide whether the top or the bottom chimaeric was more like the central original. The combination of 10 faces, normal and mirror reversed versions, and top or bottom positioning of each chimaeric produced 40 trials.

In February 1986 K.L. was tested on this task with upright stimuli. On 34/40 trials ($z=4.27$, 2-tailed $P<0.001$) he chose the chimaeric made from the side of the central print falling to his right and its mirror image as looking more like the original. Again, this is unlike the modest bias toward the left side + mirror image chimaeric that would be expected for normal subjects [26, 28, 47]. A further test in May 1986, in which all of the stimuli (top, centre, and bottom) were inverted, once more showed a pronounced bias toward choice of the chimaeric made from the side of the central stimulus falling to K.L.'s right (36/40 trials; $z=4.90$, 2-tailed $P<0.001$).

Identification of pairs of chimaeric faces (May 1986)

A final chimaeric faces task was given to K.L. to explore further the finding from the second version of the chimaeric expressions task, that K.L. was influenced by the left or right side of each chimaeric rather than the chimaeric's left or right position in the display.



Fig. 5. Examples of right half-face, right internal features, and right external features stimuli.

A VERTICAL**B** HORIZONTAL

Fig. 6. Examples of chimaeric faces from expression perception tests, with vertical (6A) or horizontal (6B) arrangement of chimaeric pairs.

MIRROR IMAGE

+

LEFT SIDE



ORIGINAL



MIRROR IMAGE

+

RIGHT SIDE



Fig. 7. Example of chimaeric faces from resemblance task.



Fig. 8. Example showing arrangement of pairs of chimaeric faces from identification task.

Chimaeric faces made from the left and right sides of the faces of 10 famous people were positioned side by side, as in Fig. 8.

K.L. was asked to identify the faces in each chimaeric. He had previously been shown each of the 10 faces used, and told whose face it was. The left and right sides of each face then occurred once in each of the possible positions in the display during the course of the task. On the 20 trials involved K.L. made seven errors, all involving the left side of one of the chimaerics (sign test, $N=7$, $x=0$, two-tailed $P<0.05$). Four of these errors were to the left side of the leftmost chimaeric, and three were to the left side of the rightmost chimaeric, confirming that his problems relate to the side of the face rather than its spatial position.

Identification of faces gradually revealed in left-right or right-left direction (March 1986)

Part of our interest in using chimaeric stimuli with K.L. was that perceptual asymmetries are known to occur for normal subjects and, as we have seen, these are opposite to those found for K.L. A further demonstration of a similar phenomenon is that normal people are better at identifying faces from the leftmost than from the rightmost features [47]. This seemed most unlikely to be the case for K.L., and a formal test was carried out.

Full-face photographs of 10 famous people were shown to K.L. using a technique in which one-sixth of the face at a time was revealed, beginning at the extreme left edge or the extreme right edge of the picture. Each face was used once in the correct orientation, and once mirror-reversed to control for any asymmetry of the facial features themselves. The faces were those of people we expected K.L. to recognize by the time that the whole face was revealed, based on his past performance. As expected, in 15/20 cases (considering the normal and mirror-reversed photographs together) he recognized the face more quickly when it was revealed from the rightmost edge toward the left (sign test, $N=20$, $x=5$, two-tailed $P<0.05$).

Identification of whole faces, left half-faces, and right half-faces (May 1986 and July 1986)

The fact that K.L. was so consistently poor at recognizing left half-faces eventually led us to wonder whether he derived *any* useful information from this region of the face. Thus we decided to compare his performance at recognizing (naming) left half-faces, right half-faces, and whole face photographs. The particular focus of interest was in whether performance with whole faces would be any better than performance to right half-faces; i.e. whether the presence of the left-half in a whole-face photograph would assist identification.

Full-face photographs of 10 famous people were used to make test stimuli. Each of the 10 famous people was presented once as a whole face, once as a left half-face, and once as a right half-face in the course of the test. Training at recognizing the whole face views was given before the test session began. The entire test was then repeated later in the same day (May 1986) and again after an interval of 2 months (July 1986).

Mean reaction times (in seconds) for correct responses, and error rates, are presented in Table 4. It is clear that K.L.'s error rates are much the same for right half-faces and for whole faces, but higher for left half-faces. Thus there is no evidence in the error rates of any advantage of whole faces over right half-faces, though K.L.'s characteristic impairment for left half-faces is, of course, replicated.

Much the same conclusion holds for the reaction times. A one-factor analysis of variance of the correct reaction times to each of the 10 stimulus faces was carried out to determine the effect of stimulus type (left half-face, right half-face, or whole face; repeated measure). A significant effect was found [$F(2, 18)=4.37$, $P<0.05$]. Tukey tests ($\alpha=0.05$) showed that

Table 4. Mean reaction times (in seconds) for correct responses, and error rates, for identification of left half-faces, right half-faces, and whole faces by K.L. (May 1986 and July 1986)

RT (sec)			Errors (max = 30)		
Left half	Right half	Whole face	Left half	Right half	Whole face
3.55	2.33	1.71	11	4	3

responses to left half-faces were slower than to whole faces, but that reaction times to right half-faces and to whole faces did not differ from each other.

This test thus produced no substantial evidence of K.L.'s making use of information from the left side of the face in recognizing a whole-face photograph. We can conclude that his use of left-side information is at best severely limited.

Identification of half-faces presented to the right of fixation (April 1986)

We have noted that K.L.'s problems with faces seemed to occur throughout his field of vision, and thus could not be attributed to his hemianopia. In order to confirm this conclusion by formal testing, left and right half-faces were presented at tachistoscopic exposures within K.L.'s intact right visual hemifield. To check for central fixation, a digit was presented between the fixation point and the half-face on every trial; K.L. was asked to report the digit before identifying the half-face. Hence we ensured that for every trial the half-face stimulus fell to the right of a digit that K.L. could identify, and was thus well within the area of intact vision.

Full-face photographs (in normal or mirror-reversed prints) of six famous people were cut along the vertical midline for use as stimuli. On each trial a left or a right half-face was presented for 150 msec, and followed immediately by a pattern mask consisting of face fragments. The half-faces subtended a horizontal visual angle of $2^{\circ} 30'$, and the centre of each half-face was offset to the right of the fixation point through a horizontal visual angle of $3^{\circ} 45'$. On every trial, one of the digits 2, 3, 4, or 5 was presented simultaneously with the half-face, and positioned between the fixation point and the half-face. K.L. was asked to report the digit and then name the half-face. He was told who the six people were whose faces would appear in the test. A practice session was used to emphasize the importance of fixating centrally before each trial, and reporting the digit correctly.

Across 144 trials (72 with left half-faces, 72 with right half-faces), K.L. always reported the fixation control digits correctly. He made 40 errors to the left half-faces and 21 errors to right half-faces, thus showing a statistically significant tendency to make more errors to left half-faces ($z = 2.30$, 2-tailed $P < 0.05$), even though these were presented in his intact right visual field. The tendency to make more errors to left than to right half-faces held for all of the six faces used (sign test, $N = 6$, $\alpha = 0$, 2-tailed $P < 0.05$).

To confirm the accuracy of the fixation control, K.L. was shown the fixation digits presented for 150 msec in the left visual field or in the right visual field. He correctly identified all of the right visual field digits, but only 3/12 left visual field digits (chance level). Hence he must have fixated correctly during the test session, which implies that all of the half-faces fell in his right visual field.

In the test used here, the left and right half-faces were offset to an equidistant extent to the right of K.L.'s point of fixation. One consequence of this, however, is that the parts of the

half-face containing the nose and mouth would be slightly closer to fixation for right half-faces. As a check that this was not crucial to the result, a further test was run in which the half-faces were aligned as if they had been part of a complete face offset by $3^{\circ} 45'$ min (i.e. with the right-hand edge of left-faces offset by $3^{\circ} 45'$ min, and the left-hand edge of right half-faces offset by $3^{\circ} 45'$ min). This procedure puts the *right* half-faces at a definite disadvantage, since they will fall in an area of lower acuity. Despite this, K.L. still recognized 6/6 of the faces used more accurately from right than from left-halves (sign test, $N = 6$, $x = 0$, two-tailed $P < 0.05$).

DISCUSSION

Because of the large number of tests carried out with K.L., we begin by summarizing the principal findings:

(1) K.L. showed impaired processing of the left-half of faces across a range of tasks, including those involving chimaeric faces, half-faces, and construction of faces from individual features. Because mirror-reversed stimuli were included in many of the tests, we can be certain that this problem relates to the left-half of the face as seen by K.L., rather than to any asymmetry in the distribution of facial features, or asymmetric impairment of K.L.'s face memory. In contrast, he showed no impairment to half-stimuli drawn from categories other than faces, such as objects or car-fronts. Particularly striking is the fact that K.L.'s performance did not differ between right half-faces and right half-car-fronts either in terms of accuracy or reaction time, yet he was severely impaired in his performance to left half-faces, whilst remaining unimpaired with left half-car-fronts.

(2) When K.L. first experienced this problem, he showed no signs of visual neglect in reading or in item cancellation tasks.

(3) In chimaeric face tasks, K.L. was impaired at recognition of left sides, and his perception of expression and of resemblance between stimuli was heavily biased toward the chimaerics' right sides. The tendency to neglect the left side of individual chimaeric faces was found even when they were positioned at the right hand side of a display containing more than one chimaeric face.

(4) Impaired recognition of left half-faces was also found when these were presented in isolation. This finding held both for identification and for familiarity decision, and was as evident for personally familiar faces as for famous faces. Both internal and external features of left half-faces were poorly recognized. Impaired recognition of left half-faces was found even when they were tachistoscopically presented so as to fall entirely in K.L.'s intact right visual field. Moreover, K.L. was better able to identify faces when they were gradually uncovered from the rightmost than from the leftmost edge.

(5) K.L.'s problem with the left side of faces was not affected by inversion. Instead, the problem was equally evident for upright and inverted faces; in both cases affecting the side of the face falling to his left.

(6) Although he was impaired across a wide range of tasks involving left half-faces, K.L. could correctly assign left half-faces to the 'human face' category in a task involving human face, dog face, and tree stimuli.

To the best of our knowledge, this type of problem has never been described in detail before. There are, however, some relevant observations in the clinical literature. The work with split-brain patients showing the importance of the right hemisphere to the perception of chimaeric faces is well-known [42], and related findings have been reported for normal

subjects [46]. Similarly, KOLB *et al.* [35] demonstrated that patients with right temporal or right parieto-occipital lesions did not show the usual perceptual bias in favour of the left side of face chimaerics found for both upright and inverted faces in normal subjects. DE RENZI *et al.* [20] found that patients with right brain damage scored significantly lower than patients with left hemisphere lesions on a test which included the matching of half-faces to a display of whole faces, though they did not comment on any difference in performance between left and right half-faces. BRUYER [11] also noted that patients with brain injuries affecting the right cerebral hemisphere could have problems with half-face to face matching.

There are also some observations of perceptual distortions affecting left half-faces. LAWSON [38] reported one case in which ability to draw faces was compromised on the left side in a patient with unilateral neglect. In BODAMER'S [8] classic paper on prosopagnosia, he mentions that Pichler and Zador had described examples of perceptual distortions affecting one side of the face more than the other. Most relevant of all, perhaps, is the second case described by BRUST and BEHRENS [10] in their paper on 'release hallucinations' following posterior cerebral artery occlusion. This patient, who was considered to have suffered an infarct in the territory of a posterior cerebral artery, experienced transient visual illusions in which 'the right half of people's faces (i.e., to the patient's left) seemed to melt, "like clocks on a Dali painting", and took on yellow or violet colours. Objects other than faces were not involved, and the facial distortions were sharply limited to one-half only' [10, p. 432]. An EEG recording during one of his neurological episodes showed frequent sharp forms in the right posterior temporo-occipital area and decreased amplitude of the alpha rhythm on that side.

We will discuss three issues raised by our findings with K.L. These concern the role of attentional mechanisms in face perception, our hypothesis that the problem can be characterized as a domain-specific form of unilateral neglect, and its relation to metamorphopsia.

Attentional mechanisms in face perception

K.L.'s problems with left half-faces could be demonstrated across a wide range of tasks, including face construction and the determination of identity, expression, or resemblance between unfamiliar faces. Thus they affected all of the aspects of face processing we were able to test, with no evidence to indicate that only part of the face processing system was involved. Because there is considerable evidence that properties such as identity and expression are determined largely independently [9], we reasoned that K.L.'s impairment must be affecting early stages of face processing. A perceptual impairment was thus an obvious candidate, though it would have had to be restricted to faces, because K.L. showed no signs of equivalent problems with other types of visual stimuli. We cannot, of course, be absolutely certain that there was no equivalent impairment for *any* class of stimuli other than faces. One cannot prove the null hypothesis. But the stimuli we used were of types for which some difficulty would be expected for a patient suffering the type of impairment associated with the 'perceptual' form of prosopagnosia.

Any perceptual impairment responsible for K.L.'s face processing problem would have to be 'central' in nature, however, because left half-faces were affected even when they were presented in isolation (i.e. the impairment was not restricted to chimaeric stimuli), and because this problem occurred even in K.L.'s otherwise intact right visual field. Hence it is the *mental representation* of the left side of familiar faces that seems to be affected. K.L.'s condition is thus quite different to the 'hemiagnosic' problems to left visual field stimuli that have been described by MAZZUCCHI *et al.* [44].

An alternative view would be that K.L.'s problem lies in *attending* to the left side of seen faces. Face-specific attentional mechanisms might subservise useful social functions, and there is evidence that even newborn babies are attentive to faces [27]. Moreover, studies of the processing of chimaeric faces by adults and children have produced evidence consistent with the existence of an asymmetric bias of attention *toward* the left side of seen faces (i.e., the side falling to the viewer's left) for right-handers [26, 28, 33, 35, 40, 41, 47, 53]. Since we used the same techniques with K.L., we will consider this literature in more detail.

GILBERT and BAKAN [26], using a technique introduced by WOLFF [53], demonstrated that right-handers tend to choose a composite chimaeric made from the left-half of a face photograph and its mirror-image as being more like the original than a right-half + mirror-image chimaeric, whereas there is no equivalent tendency for left-handers. The result has been replicated by RHODES [47], and an extension was made by KOLB *et al.* [35], who demonstrated an equivalent effect (choice of left-half + mirror-image chimaerics as more like the original) with inverted faces and right-handed normal subjects, but no asymmetry in patients with right temporal or right parieto-occipital lesions. A related technique involving the perception of chimaeric expressions has been used by LEVY *et al.* [33, 40, 41], who have also found a left-side bias for right-handers, and reduced or no bias for left-handers.

Often, people try to account for such perceiver bias effects by proposing that they relate to the well-known left visual hemifield superiority for face processing by normal subjects [23, 29, 48]. But there are difficulties with this position. The perceiver bias effects are found in free vision, without the need to restrict viewing of the left side of each face to the left visual field, and when this restriction has been observed (e.g. in tachistoscopic presentation) the perceiver bias asymmetry is not always found [28, 47]. Furthermore, KOLB *et al.*'s [35] demonstration of equivalent asymmetry to upright and inverted chimaerics is inconsistent with an explanation based solely on visual hemifield differences for face processing, since these are eliminated by inversion [39, 55].

Similar observations led GREGA *et al.* [28] to propose that the perceiver bias reflects a hemispatial effect, in the form of a bias of a central attentional mechanism which leads to a *more effective internal representation or to more extensive processing of one side of the stimulus*.

LEVY *et al.* have also proposed that asymmetries in the perception of chimaeric faces may reflect the involvement of attentional mechanisms. They argue for individual differences in hemispheric arousal, and see hemispheric arousal as biasing attention to one side of appropriate stimuli [33, 40, 41].

The idea of attentional mechanisms in face perception seems to us useful in that it may be able to account not only for the pattern of finding from studies of normal subjects, but also for K.L.'s performance. Whilst normal right-handed subjects may show a bias toward information from the left-half of chimaeric faces, K.L., it will be recalled, showed a most pronounced asymmetry in the opposite direction. He found it very difficult to make any use of left half-faces at all. In other respects, though, such as the existence of equivalent problems with inverted faces, his performance was consistently influenced by the same factors as that of normal subjects. K.L. can thus be considered to have suffered perturbation of the face-specific attentional mechanism, leading to an abnormal and exaggerated distribution of attention toward the right side of seen faces.

In contrast to an attentional explanation, the idea that asymmetries in chimaeric face perception reflect visual hemifield differences for face processing cannot explain K.L.'s problems at all, since they were found to be present even in his right visual field. Again, we

must thus emphasize that it is the *mental representation* of the left side of seen faces which is affected.

A domain-specific form of unilateral neglect

We propose, then, that K.L. is experiencing the effects of a disruption of face-specific attentional mechanisms. His impairment is, in our view, best characterized as a domain-specific form of unilateral neglect.

Evidence that unilateral neglect may take different forms has been accumulating for some time, with findings of dissociations between neglect of visual and auditory [4] and visual and tactile input modalities [15], personal and extrapersonal space [6], and between symptoms found for different materials within the visual modality [16, 32].

Most striking of all has been COSTELLO and WARRINGTON'S [16] demonstration of a dissociation between visuospatial neglect and neglect dyslexia. Their patient, J.O.H., had lesions affecting the left and right parietal lobes. When reading, J.O.H. showed left-sided neglect dyslexia, making errors at the beginnings (left) of words. In visuospatial tasks, however, *right-sided* visuospatial neglect was evident in line bisection or copying tasks. COSTELLO and WARRINGTON [16] thus emphasize that different neuropsychological mechanisms may underlie the different manifestations of unilateral neglect, and suggest that the errors affecting word-beginnings found in cases of neglect dyslexia may be due to an abnormal distribution of attention in the visual word form system. Consistent with this suggestion, COSTELLO and WARRINGTON [16] reported that the neglect dyslexic patient, J.A.F., whose errors had been described by BAXTER and WARRINGTON [2; see also 51], showed no evidence of more general neglect.

A further case of dissociation between word misreadings and visuospatial neglect is mentioned by BISIACH *et al.* [7, pp. 479–480]. Their patient, MT, showed no neglect in an item-cancellation task, and yet would read only the last two letters of 10-letter words.

Neglect dyslexia, then, may be a disorder specific to reading that affects the left side of seen words. Our view is that K.L. experienced a comparable domain-specific form of neglect affecting the left side of seen faces. This parallel impresses us in two ways. First, neglect dyslexia obviously arises at a relatively early (albeit word-specific) stage in the reading process, since the errors made to word beginnings are unaffected by the misread word's phonology or semantic category. Similarly, K.L.'s problem affected the left side of faces in nearly all face processing tasks, even though it was apparently face-specific. Second, the errors to word beginnings found in neglect dyslexia are unaffected by the word's position in the visual field [22, 34], and K.L.'s errors to left half-faces share this property.

Our hypothesis is thus that *domain-specific mechanisms involved in the analysis of different aspects of a visual scene may be independently susceptible to unilateral neglect*, producing visuospatial neglect when object location mechanisms are compromised, neglect dyslexia when reading is affected, and K.L.'s problem when face processing is affected. We have already noted that when K.L. presented with this facial neglect he did not experience any other neglect-like symptoms that we could detect, and that after his later stroke that led to visuospatial neglect and neglect dyslexia his problems with faces remained unaltered.

We have suggested that facial neglect involves an impairment of attentional mechanisms involved in face processing. The debate between attentional [31, 49] and representational [3, 5] theories of neglect is, however, by no means resolved, with different lines of evidence favouring either position. Moreover, we are by no means certain that the two types of theory are necessarily mutually exclusive. Our preference for an attentional account for K.L. is thus

based in large part of the ease with which his problems can be related to the 'chimaeric face' literature. Also in favour of the attentional account, though, is the fact that K.L. experienced equivalent problems to upright and inverted faces. Inversion seriously affects the construction of facial representations [39, 55, 57], so that it might have been expected to have a differential effect on any purely representational account of K.L.'s disorder.

Relation to metamorphopsia

Metamorphopsic patients complain that faces look distorted. BODAMER [8] drew attention to this in his paper on prosopagnosia. His third case was a patient who saw all faces distorted; in describing a face of a familiar person he was looking at he commented that the nose seemed to be turned sideways by several degrees, one eyebrow looked higher than the other, the mouth was askew, and the hair shifted, like an ill-fitting cap. According to the patient, only faces were distorted in this way. Yet he could recognize familiar faces without much difficulty. The condition apparently cleared up after about 8 days.

BODAMER [8] attached considerable importance to the point that face recognition was possible despite such distorted face perception, and this was reiterated by HÉCAEN and ANGELERGUES [30]. Their patients commented that faces were "distorted and contorted like some sketches of Picasso, I should say", or that "you have stretched lips, a thick nose, and you are grinning. You don't look nice at all. Your eyes are stretched and have big circles under them." Yet HÉCAEN and ANGELERGUES [30], like BODAMER [8], maintained that such patients often find recognition easier than do truly prosopagnosic patients. This is not, however, inevitably so. WHITELEY and WARRINGTON's [52] case 3, who said that people's faces looked strange and ugly, "like fish heads", was also impaired at recognizing familiar faces.

Because of the previous reports of metamorphopsic disturbances of face perception affecting one side of the face more than the other [8, 10], we considered the possibility that this was also what underlay K.L.'s difficulties. His initial description of his problems certainly seemed to have a metamorphopsic element, though this was not very pronounced. He felt that faces looked 'different', or 'deformed', and that the eyes were somehow misplaced, but did not describe the florid distortions found in some of the reports we have cited. The 'bottled glass' effect that K.L. initially noticed bordered the edge of his hemianopic visual field, and did not seem to relate to the problem with faces, which occurred in all parts of his field of vision.

The drawback of the 'metamorphopsic' account of K.L.'s difficulties, however, is that these metamorphopsic symptoms were only present when we first saw K.L. Later, he was certain that they had all 'cleared up', including both the distortions of facial appearance and the 'bottled-glass' effect. Fairly rapid resolution of metamorphopsic symptoms is also a feature of other cases [8, 52]. Yet K.L.'s problems in processing left half-faces were still readily evident long after he was no longer experiencing any metamorphopsia. One might perhaps claim that the metamorphopsia was still 'really' there, but that K.L. had somehow got used to it. We do not think that such a claim would be very helpful. Metamorphopsia must be defined in terms of subjective report and, subjectively, K.L. no longer experienced it. The persistence of the face processing deficit thus demonstrates that it is unrelated to subjectively experienced metamorphopsia, and requires a different type of explanation. We have offered an account in terms of a domain-specific form of unilateral neglect. A plausible speculation, though, is that some forms of metamorphopsic disturbance could be a reflection of severe forms of facial neglect, rather than the other way round.

Although we have characterized K.L.'s impairment as a domain-specific form of unilateral neglect, we accept that this conclusion must await confirmation or refutation by studies of other patients with comparable problems. Our main purpose has been to describe and investigate a disabling impairment of face processing that has hitherto itself been neglected by neuropsychologists. We hope that this will stimulate further investigations of this intriguing neuropsychological condition.

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