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A CASE OF INTEGRATIVE VISUAL AGNOSIA

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SUMMARY

A single case study of a patient with visual agnosia is presented. The patient had a marked impairment in visual object recognition along with good tactile object identification and a preserved ability to copy. Detailed investigations demonstrated impaired perceptual processes, with the patient's identification strongly affected by duration of stimulus exposure and by using overlapping figures. However, his stored knowledge of objects was shown to be intact. The results demonstrate that agnosia may be determined by a specific deficit in integrating form information; and that the input description for visual object recognition, disrupted in this patient, is functionally separate from stored object descriptions, which are intact. The implications of the results for understanding visual agnosia and for theories of normal visual object recognition are discussed.

INTRODUCTION

Visual agnosia is a severe modality-specific deficit in the recognition of visually presented objects. It is a recognition, rather than a naming deficit, since visual agnosic patients are unable to gesture the use or to show any recognition of the objects they fail to name. Typically, discussions of visual agnosia centre around Lissauer's (1890) distinction between apperceptive and associative agnosia. Lissauer argued that visual object recognition was composed of two primary independent stages; apperception, the process of constructing a perceptual representation from vision; and association, the process of mapping a perceptual representation onto stored knowledge of the object's functions and associations. Lissauer proposed that, following brain damage, patients may be impaired in either the apperception or the association process, with both impairments giving rise to a deficit in visual object recognition.

There have been several cases documented where visual object recognition deficits appear to be consequent on an impairment in establishing adequate perceptual representations of visual forms. For instance, the patient reported by Efron (1968) and Benson and Greenberg (1969) appeared to be impaired at almost any task requiring the discrimination of shape, despite having intact discrimination of size,

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intensity, distance and movement (*see also* Campion and Latto, 1985; Campion, 1987). Clearly such an impairment in using even simple shape information will render object recognition deficient. According to Lissauer's definition, such patients appear impaired in the apperception process.

In contrast to the above types of patient, other patients with visual object recognition deficits may be relatively good at copying the objects they fail to recognize (e.g., Rubens and Benson, 1971; Ratcliff and Newcombe, 1982) and at matching photographs of objects taken from different viewpoints (e.g., Taylor and Warrington, 1971; Warrington, 1975). Indeed, Riddoch and Humphreys (1987) have recently documented the case of a patient who was poor at matching objects on the basis of their associative relations, and yet who was good at discriminating pictures of real objects from pictures of meaningless distractors which were closely matched for visual similarity relative to their real counterparts (an 'object decision task'; *see* Experiment 3 below). With such closely matched distractors, object decisions may only be made with reference to stored knowledge about an object's structure. Thus the latter case suggests that impaired visual access to functional and associative knowledge about objects may occur in the presence of intact access to stored structural knowledge. Clearly this case indicates that visual object recognition may be impaired in the presence of a normal perceptual representation of the visual world, consistent with a deficit in what Lissauer termed the association process.

The distinction between apperceptive and associative agnosia introduced by Lissauer emphasizes a two-stage view of visual object recognition. More recent accounts of the recognition process, while consistent with a two-stage view, also propose that both the apperception and the association stages may themselves be divided into various substages (e.g., Marr, 1982; Humphreys and Riddoch, 1987). The latter accounts predict that it is possible for each of these substages to be selectively impaired following brain damage and, therefore, for different types of 'apperceptive' or 'associative' impairment to result. Indeed, it may be that patients previously classed as either apperceptive or associative agnosics may illustrate damage only to some substages.

In the present paper we report a detailed case study of a patient, H.J.A., with a marked and selective deficit in visual object recognition. This recognition deficit seems to be of a higher order than that sustained by the apperceptive agnosic patients studied by Efron (1968), Benson and Greenberg (1969), Campion and Latto (1985) and Campion (1987). Yet we present evidence for its being consequent on a residual impairment in perceptual representation. We therefore suggest that the classification scheme for agnosia be expanded to incorporate such selective deficits in particular substages in visual perception.

The paper is organized as follows. In Section 1, we discuss H.J.A.'s performance on a series of diagnostic tests used to classify patients in terms of the apperceptive-associative agnosic dichotomy. The subsequent sections are then devoted to investigations of other aspects of H.J.A.'s recognition performance. Section 2 deals with

H.J.A.'s recognition performance. Section 3 deals with his semantic knowledge and access to such knowledge from vision. Section 4 deals with his short and long-term visual memory. Section 5 deals with his ability to use context to facilitate object recognition. H.J.A.'s visual recognition impairment is attributed to a primary deficit in his perceptual representation of visual stimuli, and this deficit coexists along with intact semantic and visual memory, and an intact ability to make use of context. The implications of the case for accounts both of visual agnosia and the processes mediating normal object recognition are discussed.

CASE HISTORY

Details of H.J.A's case history have been given elsewhere (Humphreys and Riddoch, 1984). Premorbidly, he was an executive who held responsibility for the European transactions of an American company. He suffered a stroke perioperatively in April, 1981, when aged 61 yrs. Subsequent to the stroke, his major problem was an inability to recognize common objects and faces by sight. He had acquired achromatopsia, showing a complete inability to discriminate colours. He also showed topographical agnosia, in that he was unable to recognize his environment by sight and he could easily become lost if moved away from a well-learned route. His reading was reduced to an accurate but slow letter-by-letter process. He had only a minor writing problem (*see* fig. 1), but was

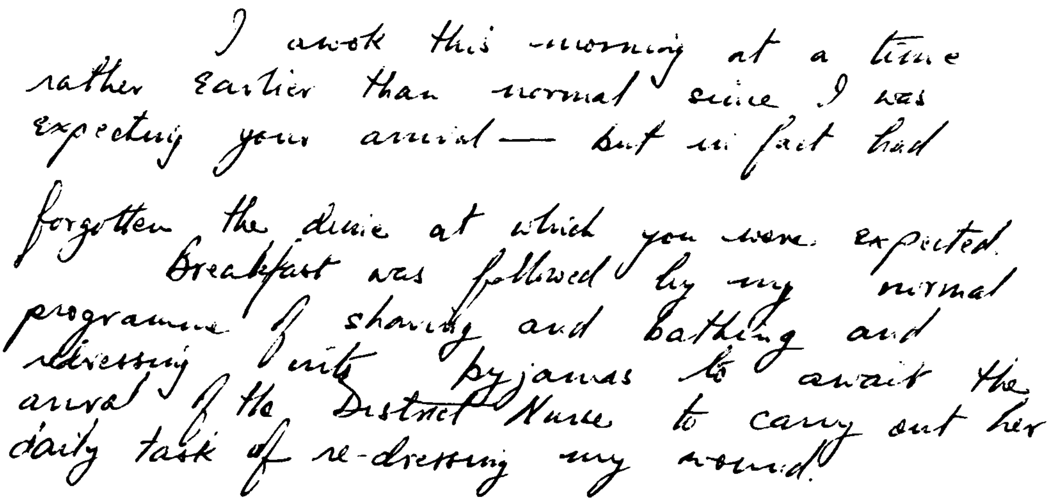


FIG. 1. Example of H.J.A.'s handwriting.

typically unable to read what he had written (the reading of handwriting being a particularly difficult task for letter-by-letter readers; *see* Warrington and Shallice, 1980). H.J.A. had no memory deficits (digit span 8–9; *see* Sections 3 and 4 in the text for discussion of his semantic memory, his memory of the structural characteristics of objects, and his short-term visual memory).

An initial CT scan (May 1981) failed to reveal any marked neurological abnormalities, but a subsequent scan (June 1984) demonstrated extensive infarction extending forward in both occipital lobes in the distribution of the posterior cerebral arteries (*see* fig. 2). Perimetric testing (using both the Goldman and the Octopus apparatus) showed a superior altitudinal defect of both the left and right visual fields (*see* fig. 3). Responses from the lower fields were normal. Snellen acuity was normal.

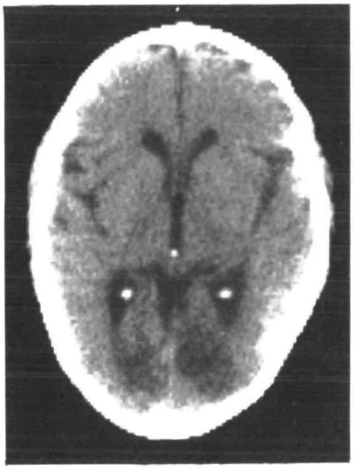


FIG. 2. CT scan, June 1984, showing bilateral occipital infarction.

Visual evoked potential recordings showed normal patterns to stimuli presented to his lower visual fields, and no response to stimuli in his upper fields. Eye movements were recorded by both infrared and search coil techniques. Smooth pursuit movements (infrared recordings) were normal, as were horizontal saccades and downward vertical saccades to random targets at steps of 30 deg (search coil recordings). Vertical saccades upwards showed a staircase tracking pattern, consistent with his superior altitudinal field defect (*see* fig. 4). No motor deficits were apparent, or expressive or receptive speech problems.

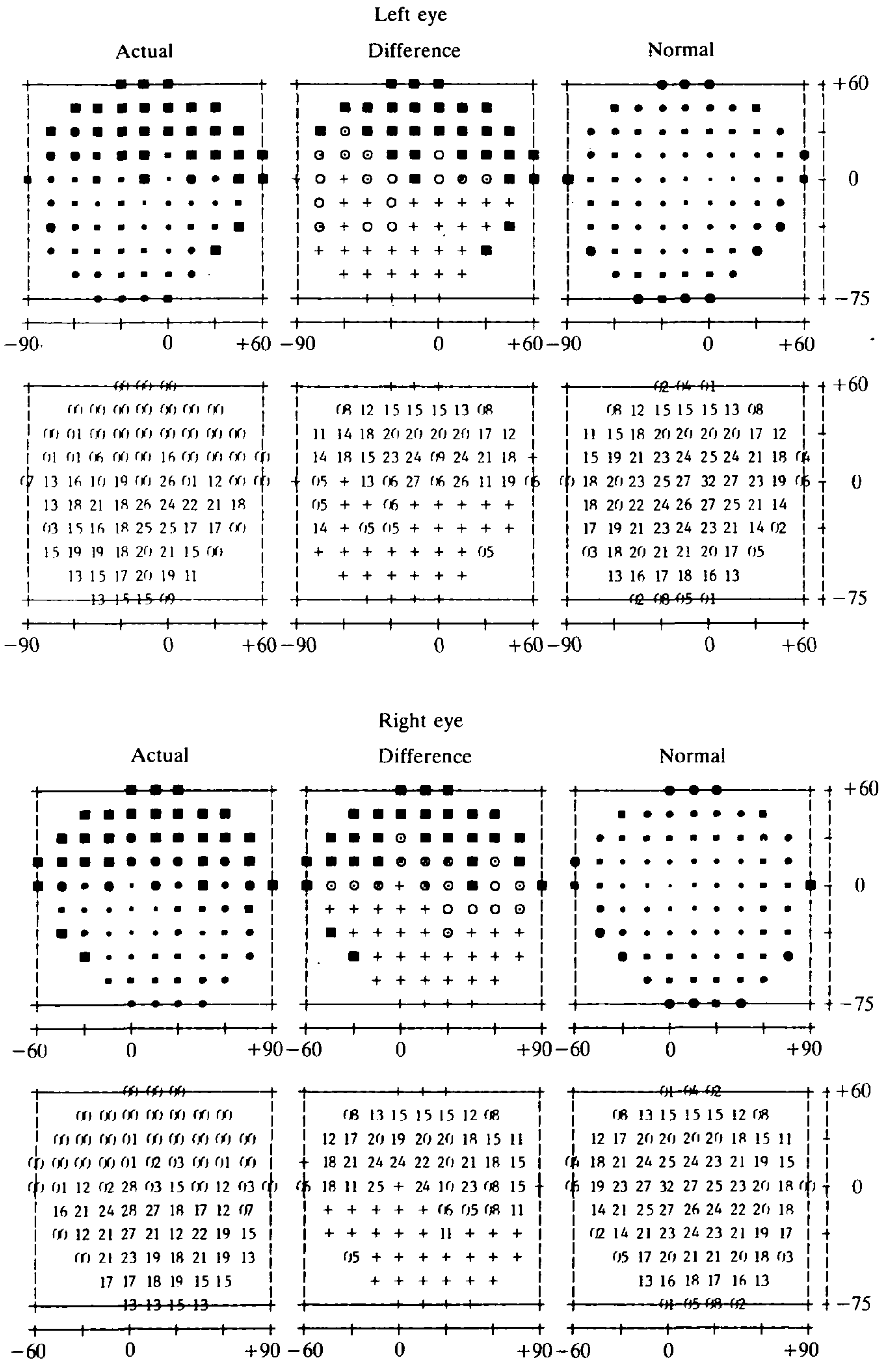
The present investigations were carried out in a number of sessions conducted between April 1981 and May 1985 during which time H.J.A.'s condition remained stable. The only slight improvement observed was in the visual recognition of very familiar household objects (knife, fork, spoon, cup, etc.). He was well orientated in time and place during all the test sessions.

NEUROPSYCHOLOGICAL INVESTIGATION

Section 1. Diagnostic tests

H.J.A. named 28/45 real common objects correctly from vision, but 36/42 of the same objects from tactile presentation. Tactile identification was reliably better than visual identification ($\chi^2 = 5.02$, $P < 0.05$). However, real objects were easier to identify from visual presentation than photographs of the same objects taken from a prototypical viewing position (21/32 vs 12/32; McNemar test of change, $\chi^2 = 4.90$, $P < 0.05$). This shows that H.J.A.'s problem in identifying objects is modality specific, and sensitive to the visual information present in the stimulus. His identification is better given the extra information present in real objects.

When H.J.A. failed to identify objects correctly, he was unable to gesture their use. On simple function match tasks, involving the matching of line drawings or photographs of physically-different objects which can be used for the same function (*see* Warrington and Taylor, 1978), he performed poorly, scoring 12/20 with line drawings and 18/26 with photographs. His performance on the function-match



□ = Difference table (normal minus actual): + = deviation < = 4 dB; ○ = deviation 5 . . . 9 dB;

⊙ = deviation 10 . . . 19 dB; ● = deviation > 19 dB; ■ = absolute defect.

FIG. 3. Results of Octopus perimetric recordings of H.J.A.'s visual fields.

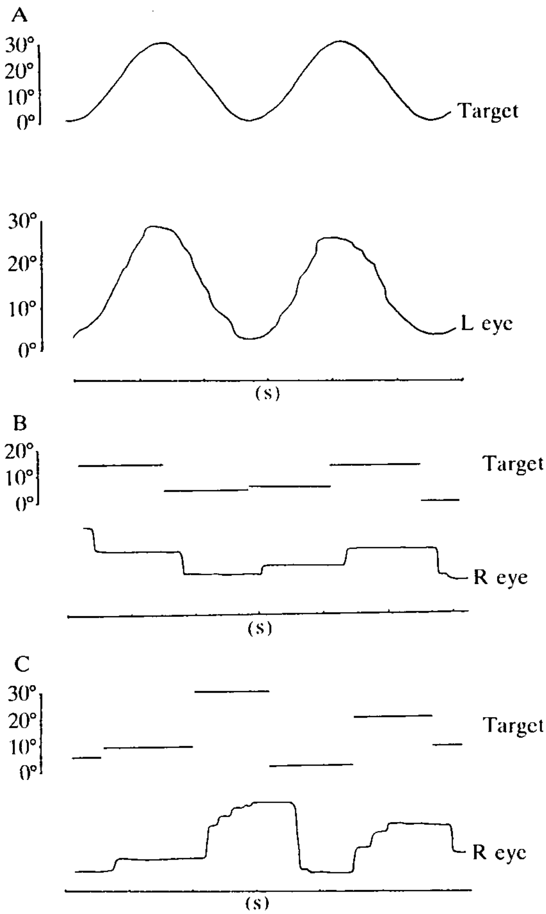


FIG. 4. Examples of H.J.A.'s eye movement recordings. A, smooth pursuit movements; B, horizontal saccades; C, vertical saccades. Smooth pursuit movements of both the left and the right eyes were made. Only left eye movement is shown here.

task with photographs was worse than his ability to perform 'physical' match tasks. For instance, it was worse than his matching of photographs of foreshortened objects across different viewpoints (24/26; *see* Humphreys and Riddoch, 1984; Fisher Exact Probability $P=0.03$). The function-match task is not more difficult than different-view matching task, as right hemisphere-damaged patients who are impaired at different-view matching can find the function-match test easier (e.g. D.B., reported in Humphreys and Riddoch, 1984, scored 23/36 on the function match test and 12/26 on the foreshortened-view test $\chi^2=8.74$, $P<0.01$). H.J.A. is relatively impaired at matching objects on the basis of their functions. Also, his function match performance was related to his ability to name the objects used ($Z=1.71$, $P<0.05$; Kendall's Tau $=0.374$ for the line drawings; $Z=2.05$, $P<0.025$, Kendall's Tau $=0.398$ for the photographs). There was no reliable relation between his different-view matching performance and his ability to name the objects involved

($Z < 1.0$; Kendall's Tau $= 0.091$). Thus he can match objects across different viewpoints without knowing their identities, whilst he tends not to know the function of objects when he fails to identify them. This confirms that the problem is not simply one of naming.

H.J.A. typically named stimuli using deliberate articulated feature-by-feature descriptions, irrespective of whether the stimuli were real objects, line drawings or photographs. An example of a feature-by-feature description is given in Fig. 5. There were also indications of incorrect grouping of the local parts of objects. For instance, when shown a photograph of a paint-brush with a wooden handle, H.J.A. responded that 'it appears to be two things close together; a longish wooden stick and a darker, shorter object, though this can't be right otherwise you'd have told me'.

In nearly all cases H.J.A.'s naming latencies were abnormally prolonged, being of the order of 25 s for correct responses and 41 s for incorrect responses. Such long latencies suggest that his visual object recognition is typically based on an extensive search of his stored knowledge about objects. Errors occur when he fails to match the input with his stored knowledge and, on such occasions, he seems to carry out an exhaustive search of his stored knowledge until a partial match occurs.

H.J.A. made solely visual naming errors or omissions. This suggests a problem in gaining access to semantic and name information from vision, perhaps because he has difficulty attaining an appropriate perceptual representation. At any rate, his failure to make any semantic errors is contrary to the proposal that his recognition deficit reflects an impaired semantic system (*see* Riddoch and Humphreys, 1987).

H.J.A. also tended to find objects from categories with 'structurally similar' exemplars (e.g., animals, birds, fruit, insects and vegetables) more difficult to identify than objects from categories where the exemplars tend to have more distinctive structures (e.g., body parts, clothing, furniture, implements and vehicles) (*see* Riddoch and Humphreys, 1987). He named 24/40 line drawings of objects from categories with structurally distinct exemplars and 12/35 objects from categories with structurally similar exemplars. This difference is statistically significant $\chi^2 = 4.87$, $P < 0.05$) (*see* Appendix for arguments concerning other accounts of this result).

The consistency of H.J.A.'s performance was assessed by re-presenting 25 of the line drawings from both the structurally similar and the structurally distinct categories. He named 16/25 (session 1) and 17/25 (session 2) of the objects from the structurally distinct categories, and 9/25 (session 1) and 8/25 (session 2) of the objects from the structurally similar categories. For both category types, his performance was close to that expected if there was perfect consistency across the sessions, whilst performance differed from that expected if there were complete independence.

For the structurally distinct objects, H.J.A.'s overall probability of correct naming was 0.66. Assuming complete independence, he would score 10.89

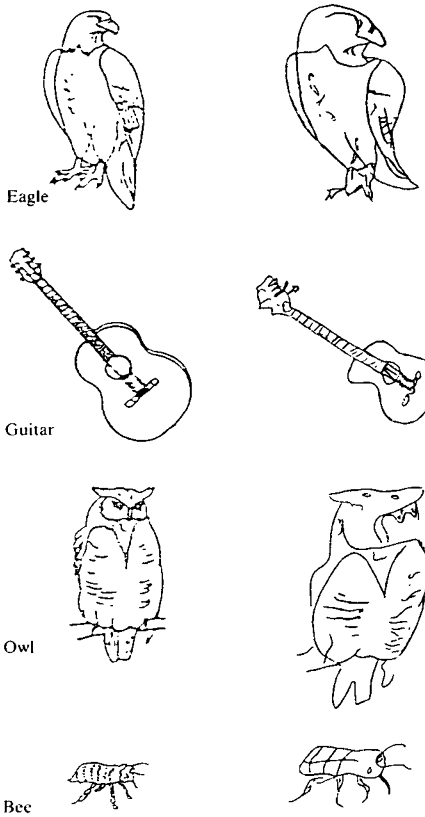


FIG. 5. Examples of H.J.A.'s copying of objects he fails to identify. In each example, the original line drawing is shown on the left and H.J.A.'s copy is shown alongside it. He named the eagle as 'a cat sitting up', the guitar as 'some kind of a machine, a press', the owl as 'a pattern', and the bee as 'an animal with horns and a tail, a rhino?'

($0.66 \times 0.66 \times 25$) correct on both occasions, the number of stimuli which he names correctly on one occasion and incorrectly on the other should be 5.61 ($0.66 \times 0.34 \times 25$), and the number which he fails to name on both occasions should be 2.39 (0.34×25). The observed frequencies (15 correct on both occasions, 2 correct on the first and incorrect on the second, 1 correct on the second and incorrect on the first, and 7 incorrect both times) differ significantly from those expected from complete independence ($P < 0.05$, goodness of fit with 3 deg of freedom). The observed frequencies are also close to those expected from complete dependence (16.5, 0, 0, 8.5). Finally, if there was complete independence, performance accuracy in the second test should be the same for the items wrong on the first test as for the items right. Out of 9 errors on test 1, only 2 were correct on test 2; out of 16 correct responses on test 1, 15 were correct on test 2. Performance on the items wrong on test 1 differed from that on the items correct ($\chi^2 = 10.46$).

Equivalent results obtained in the analysis of his performance on structurally similar objects.

In contrast to his poor visual object recognition, H.J.A. was good at copying objects. Examples of some of his copies of line drawings, which he failed to identify, are given in fig. 5.

Summary of the diagnostic tests

H.J.A. is impaired at recognizing visually presented objects. This impairment is most severe for line drawings and least severe for real objects. Nevertheless, even with real objects he is worse when they are presented visually than when they are presented tactilely. H.J.A.'s visual recognition performance is consistent across items, and is characterized by slow feature-by-feature descriptions. His naming errors are always visually related to the target objects, suggesting some form of deficit in perceptual representation. However, H.J.A. is able to copy objects which he shows no sign of recognizing, and he can match objects accurately across at least some transformations of viewpoint. Thus he has a marked deficit in visual object recognition along with at least some intact elementary perceptual functions. For instance, intact copying indicates the ability to trace contours visually and to mark the positions where breaks in inspection occur (*see* Ullman, 1984). H.J.A.'s intact copying, alongside his visual recognition impairment, might be taken to suggest a classification in terms of associative agnosia. In the following sections, we examine various aspects of H.J.A.'s object recognition system in more detail so that we may better understand the exact nature of the deficit. Of particular interest was whether H.J.A.'s perceptual representation from vision was impaired, despite his good copying and different-view matching.

Section 2. Tests of perceptual representation

General examination

Previous work suggested that H.J.A. had relatively good perception of the component dimensions of visual form; he showed normal discrimination of line length, orientation and position (Humphreys and Riddoch, 1984). He also performed quite normally on a series of standard illusions (the Necker cube, the Müller-Lyer, Ponzo and Zöllner illusions), indicating sensitivity to depth information induced by local form cues. H.J.A. was further able to perceive subjective contours. For instance, he described Kanizsa's triangle (Kanizsa, 1976; Frisby 1979, p. 118) as 'two triangles superimposed: the points of one triangle pass over and to the centres of three surrounding solid circles'. He could also see depth from stereo disparity information when shown filtered anaglyphs of random dot stereograms (Julesz, 1971).

We also examined H.J.A.'s ability to detect ambiguities in pictures. He was able to detect some ambiguities in the Hogarth engraving given in Gregory (1970, p. 51); for instance, the 'rod held by the eighteenth century gentleman is ridiculous since it reaches too far, right over to the horse and cart'. This suggests that he is able to see more than one object at a time, that he can perceive depth by perspective and that he can interrelate objects coded at different depths. The descriptions also suggest that he is better able to identify objects in context than out of context; for instance, he is typically unable to identify a horse shown in isolation and yet he had no especial difficulty in identifying horses paired with a cart (though this was done very slowly; *see* Experiments 15 and 16 below for a more detailed investigation of the effects of context on identification).

Experiment 1. Overlapping figures

So far we have documented that H.J.A. has preserved acuity, analysis of contour, use of local depth information and use of local feature cues, in addition to our earlier report of intact discrimination of line length, orientation and position (Humphreys and Riddoch, 1984). However, there are examples where H.J.A.'s perceptual representation seems impaired, such as his naming errors due to incorrect segmentation of objects into their parts.

To examine H.J.A.'s ability to segment visual information more formally, a test requiring the identification of overlapping figures was devised. The test comprised three sections, respectively, requiring the identification of letters, geometrical shapes, and line drawings of common objects. In each section the stimuli were either presented singly, in nonoverlapping groups or in overlapping groups. There were 5 such conditions for the letter and geometrical shape sections: single stimuli, nonoverlapping pairs, overlapping pairs, nonoverlapping triplets and overlapping triplets. The line drawing section contained only the single stimuli, the non-overlapping pairs and the overlapping pairs.

The stimuli were presented on single sheets (21.5 cm × 32 cm). Single letters were about 1 cm in height × 0.8 cm width and they were spaced 7 cm apart on the sheet (6 rows with 3 targets per row). Single geometric shapes were about 1.4 cm in height × 1.4 cm in width, and they were spaced similarly to letters. The line drawings of single objects were about 3.5 cm high × 4 cm wide, and they are spaced 12 cm apart (6 rows with 2 targets per row). In the paired and triplet conditions there were gaps of at least one character size between the groups. The line drawings were all drawn from a set of stimuli which H.J.A. had been able to identify on previous occasions. All the sheets were viewed from a height of about 40 cm.

H.J.A.'s performance was compared with that of 8 age-matched control subjects (mean age 69.75 yrs, range 60–86 yrs). Subjects were presented with sheets from one condition at a time and they were asked to name the stimuli as quickly as possible, working from left to right across the page. The time taken to complete each sheet was recorded using a digital stopwatch.

If H.J.A. has no perceptual impairment but only a problem associating perceptual information with stored knowledge, he should not be differentially impaired in the overlapping figures condition (relative to the nonoverlapping, baseline conditions).

TABLE 1. MEAN CORRECT REACTION TIME (IN S) PER SHEET AND PER ITEM IN THE OVERLAPPING FIGURES TEST

	H.J.A.		Controls			
			Mean		Range	
Conditions	*Per sheet*	*Per item*	*Per sheet*	*Per item*	*Per sheet*	*Per item*
Letters						
Single stimuli	11.50	0.639	7.93	0.441	5.83– 11.19	0.324–0.621
Paired nonoverlapping	21.90	0.608	13.81	0.384	11.01– 22.56	0.251–0.627
Paired overlapping	52.80	1.467	16.03	0.445	10.82– 25.66	0.300–0.713
Triplets nonoverlapping	33.60	0.622	22.29	0.413	14.34– 34.93	0.311–0.647
Triplets overlapping	56.80	1.052	23.92	0.443	16.98– 35.14	0.314–0.651
Geometrical shapes						
Single stimuli	26.80	1.489	18.35	1.019	12.37– 24.42	0.687–1.357
Paired nonoverlapping	47.71	1.325	38.92	1.081	23.98– 65.18	0.666–1.811
Paired overlapping	59.79	1.661	39.07	1.085	25.03– 65.91	0.799–1.831
Triplets nonoverlapping	80.70	1.494	65.03	1.204	35.09–133.93	0.650–2.480
Triplets overlapping	137.79	2.552	69.19	1.281	32.83–136.94	0.608–2.610
Line drawings						
Single stimuli	59.00	4.508	14.04	1.170	7.58– 40.9	0.631–3.410
Paired nonoverlapping	72.99	3.042	21.48	0.895	11.49– 49.9	0.498–2.079
Paired overlapping	118.59	4.942	23.87	0.995	12.79– 66.88	0.533–2.787

The mean correct reaction times (RTs) (s) per sheet and per item for H.J.A. and the control subjects are given in Table 1. No errors were recorded.

There was a consistent pattern of results across the three types of stimuli: relative to the control subjects, H.J.A. was differentially impaired in identifying overlapping relative to nonoverlapping stimuli. This is most clearly exemplified by his performance with letters, where the increase in RTs to individual stimuli when the stimuli were overlapping was ten times larger than the largest increases present in the control subjects. Similar effects were present with the geometrical shapes and the line drawings. In the overlapping figures test, all subjects saw the nonoverlapping forms first. For the control subjects, this led in some cases to faster RTs for the overlapping figures (e.g., with the line drawings). In contrast, H.J.A. was always slower with overlapping figures. His problem with overlapping figures occurs despite having just seen and identified the same stimuli.

H.J.A. is impaired at segmenting overlapping figures, relative to control subjects. This impairment is not stimulus specific. Since the conditions differed only in the amount of (presemantic) segmentation processes required, H.J.A.'s differential difficulty with overlapping figures is consistent with a deficit in presemantic perceptual processing.

Patients with other types of perceptual disorder also find the identification of overlapping figures difficult. For instance, we have recently screened over 50 patients for perceptual problems following cerebral vascular accidents. Of these patients, 2 showed differential problems with overlapping figures of about the same magnitude as the effects observed with H.J.A. Both patients had suffered unilateral right hemisphere damage. One had ancillary deficits in simple perceptual matching tasks requiring judgement of line length and orientation; the other manifested unilateral neglect. In contrast, H.J.A. shows good line length and orientation discrimination (Humphreys and Riddoch, 1984), and full awareness of the spatial extent of stimuli (unlike the neglect patient). Unlike these other patients, it appears that H.J.A.'s problems in segmenting overlapping figures is isolated from problems in discriminating and using contour information, and it therefore represents a selective deficit.

Experiment 2. Object decision

As a further test of H.J.A.'s presemantic perceptual processing, he was asked to perform a series of 'object decision' tasks. In all these tasks, the subject is presented with a series of line drawings. Half of the linedrawings depict common objects, half depict meaningless objects created by substituting or adding parts of different objects together. The subject is asked to decide which line drawings depict real objects and which depict meaningless objects.

As noted in the Introduction, Riddoch and Humphreys (1987) have reported data on a patient who performed object decisions normally but who was poor at matching visually presented objects related by functional association (e.g. hammer and nail). The latter result indicates that stored knowledge about the structure of objects can be separated from semantic knowledge about their function and prior association. Thus, the object decision task assesses the ability to access stored, pre-semantic structural knowledge. If H.J.A. has intact access to stored structural knowledge about objects, he should be able to perform object decisions normally; he may have difficulty only if he is unable to assemble an intact perceptual representation or if he has lost structural knowledge about objects.

Experimental 2a. Object decision with line drawings. Meaningless (distractor) objects were constructed in either one of two ways, half by substituting a feature from one real object (feature-replaced condition), the other by adding an incongruous feature to a real object (feature-added condition). The feature-replaced distractors should maintain the global shape of their parent objects better than

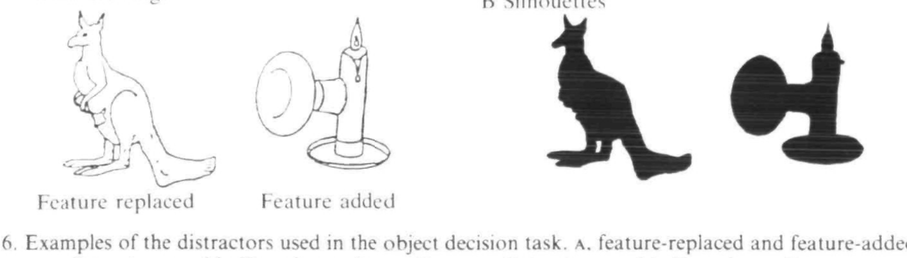


FIG. 6. Examples of the distractors used in the object decision task. A, feature-replaced and feature-added distractors used in Experiment 6a. B, silhouette distractors used in Experiment 6b.

the feature-added distractors. Categorization based solely on such global shape information should be worse on feature-replaced than on feature-added stimuli.

One hundred and twenty line drawings were used (from Snodgrass and Vanderwart, 1980). Of these, 60 were unadulterated (targets), 30 had a feature-replaced and 30 had a feature added (*see* fig. 6A). The stimuli were glued to cards and placed in a random order in front of the subject, who was asked to sort them into two piles, one for real objects and one for meaningless objects.

H.J.A.'s performance was compared with that of 11 control subjects (age range 40–60 yrs; mean age 52.5 yrs) without any history of neurological disorder. H.J.A. scored 69/120 correct (54.50%); the mean of the control subjects was 115.7/120 (96.44%), and the range was from 112/120 (93.33%) to 118/120 (98.33%). He was clearly worse than the control subjects at this task, and his performance on line drawings of real stimuli was at chance (29/60). His rejection of meaningless stimuli was slightly better if they were feature-added rather than feature-replaced (22/30 vs 18/30), though this difference was not statistically significant ($\chi^2 < 1.0$).

H.J.A.'s poor performance on the object decision task indicates that he does not have intact access to stored structural knowledge of objects from vision; this may either be because his perceptual representation of the stimulus is impaired or because he has lost stored structural knowledge about objects.

In a follow-on experiment, we tested H.J.A.'s performance using the silhouettes of some of the stimuli from the first object decision task. If he has lost structural knowledge about objects, he should be equally impaired with silhouettes and line drawings.

Experiment 2b. Object decision with silhouettes. Silhouettes of 88 of the stimuli from the first object decision task were used (stimuli were omitted if they could only be identified from internal details); 44 depicted real objects (targets) and there were 22 feature-added and 22 feature-replaced distractors (*see* fig. 6B). The procedure was exactly the same as that used for the first object decision task. There were 11 new control subjects drawn from an age range between 45 and 74 yrs; the mean age was 66.44 yrs.

H.J.A. made 63/88 (71.59%) correct discriminations, which was reliably better than his performance on the first object decision task ($\chi^2 = 4.04$, $P < 005$). The mean of the control subjects was 77.73/88 (88.33%) and there was a range between 65/88 (73.86%) and 85/88 (96.59%). The performance of the control subjects on the object decision task with silhouettes was worse than that of the control subjects on the same task with line drawings ($t(20) = 2.09$, $P < 0.05$, two-tailed).

H.J.A. is better able to perform object decisions on silhouettes of objects than on complete line drawings. This is not because silhouettes are inherently easier, since control subjects find them more difficult than complete line drawings. Presumably the contrast between his performance and that of the controls is a function of the reduced internal detail in silhouettes. Normally, internal detail adds more information about object identity and it facilitates the segmentation of an object into its parts. For H.J.A., however, internal detail hinders performance. Why should this be so? His good copying indicates that he can discriminate the local parts of objects. Also, he appears to have some information about the global shape of stimuli, since he performs tolerably well with the silhouettes (*see also* Humphreys *et al.*, 1985). His problem seems to reflect an impairment in integrating local part information with information about global shape, in that local parts are treated separately and not grouped together to elaborate the global shape description. Thus he identifies objects from feature-by-feature descriptions, and adding the local detail in line drawings exacerbates the problem since it increases the amount of grouping that must take place.

Experiment 3. Tachistoscopic identification

If H.J.A.'s visual identification is dependent on time-consuming feature-by-feature descriptions, we may expect it to be affected strongly by the exposure duration of the stimulus. Accordingly, we investigated his identification of line drawings and letters under tachistoscopic conditions.

Line drawings. Twenty line drawings of common objects (from Snodgrass and Vanderwart, 1980) were used, with the objects being chosen on the basis of H.J.A. correctly identifying them at least once on previous testing sessions. These line drawings were each presented at 4 durations: 100 ms, 500 ms, 1000 ms and unlimited (display terminated by the naming response). The stimuli and durations were presented in a fully randomized order, using a Cambridge Electronics two-field tachistoscope. Line drawings subtended a visual angle of about 2 deg in height by 2 deg in width. The first field contained a fixation cross which fell above each line drawing. H.J.A. was asked to name each depicted object. He named 16/20 of the objects with an unlimited exposure, 9/20 with a 1000 ms exposure, 8/20 with a 500 ms exposure and 3/20 with a 100 ms exposure. All his naming errors were visually related to the target, at each exposure duration. Normal subjects have no difficulty in identifying line drawings presented for 100 ms.

Letters. H.J.A. was first presented with a series of single letters at varying durations and then with a series of 2 letter stimuli. The letters were A,B,E,G and N, which could be presented in both upper and lower case. He was asked to name the letter(s) on each trial and, if possible, to report its case. Responses were counted as correct if he was able to report the letter name.

For single letter targets, there were 6 durations: 1000, 500, 100, 50, 25 and 10 ms. For 2 letter targets, only the first 5 durations were used. The stimuli were presented using a three-field Electronics Development tachistoscope. The luminance of both the fixation and the presentation field was 10 cd/m^2, measured by a spot photometer. Single letters subtended a visual angle of 0.7 deg visual angle; two-letter targets were presented in a horizontal row and subtended a visual angle of about 1.8 deg. Letters fell beneath the fixation cross.

H.J.A. was told the set of target letters and that 1 or 2 letters would be presented, and he was asked to guess if unsure. The durations were varied randomly within

TABLE 2. NUMBER OF CORRECT IDENTIFICATIONS BY H.J.A. TO SINGLE AND TWO-LETTER TARGETS AS A FUNCTION OF THE EXPOSURE DURATION

	Duration of exposure (ms)					
	1000	*500*	*100*	*50*	*25*	*10*
Single letters (chance = 4/20)	18/20	18/20	18/20	18/20	6/20	0/20
Two letters (chance = 1.2/30)	23/30	27/30	16/30	14/30	2/30	

There were 5 target letter names which could be reported; therefore chance for single letters was 1/5, and chance for two letters was 1/5 × 1/5 = 1/25.

each single and two letter block. For the single letters, there were 20 exposures at each duration; for the two-letter targets, there were 30 exposures per duration. The number of correct identifications made at each exposure duration are given in Table 2.

H.J.A. was again affected by the exposure duration of the stimulus. For single letters, performance remained stable for exposures longer than 50 ms, while it fell to about chance at 25 ms. For two-letter targets, the accuracy of reporting both

TABLE 3. ERROR ANALYSES FOR SINGLE AND TWO-LETTER TARGETS.

Single-letter targets

	Response				
Stimulus	*A*	*B*	*E*	*G*	*N*
A	–	0	1	1	1
a	–	0	3	5	1
B	1	–	0	1	0
b	1	–	1	1	0
E	1	2	–	1	0
e	1	0	–	2	1
G	0	2	1	–	0
g	5	1	2	–	1
N	3	0	0	0	–
n	2	0	1	0	–

Two-letter targets

	Response				
Stimulus	*A*	*B*	*E*	*G*	*N*
A	–	0	0	1	2
a	–	1	4	10	2
B	0	–	0	2	0
b	0	–	3	1	1
E	0	1	–	1	2
e	4	0	–	2	0
G	0	1	1	–	1
g	6	0	3	–	2
N	2	1	0	0	–
n	2	0	2	0	–

letters decreased for exposure durations of 100 ms or less, although it also only fell to chance at 25 ms.

The identification errors made by H.J.A. for both single and two letter targets are shown in Table 3. He made similar patterns of errors for both. Lower case letters tended to be more difficult to identify than upper case letters, and systematic visual confusions tended to occur, particularly between lower case 'a' and 'g'.

H.J.A.'s errors to two-letter targets were further broken down as a function of the exposure duration and the error type (*see* Table 4). As the exposure duration

TABLE 4. TYPE OF ERROR RESPONSE MADE BY H.J.A. TO TWO-LETTER TARGETS AS A FUNCTION OF THE EXPOSURE DURATION

		Duration of exposure (ms)				
		1000	*500*	*100*	*50*	*25*
a	1 letter correct	7	2	9	3	9
b	Both letters incorrect	–	1	1	3	9
c	Omission (no response)	–	–	–	–	10
d	3 letters reported	–	–	4	10	–

decreased, he did not make more errors simply by reporting only one letter correctly; rather, proportionately more errors were made because he reported both letters incorrectly and because he started to make three-letter and omission responses.

H.J.A.'s visual identification of both letters and line drawings is markedly affected by the stimulus exposure duration. His performance at short durations is relatively better with letters than with line drawings, presumably because the letters have overlearned and simple patterns; nevertheless, his impairment is not limited to one stimulus type. For both letters and line drawings he tends to make visual errors. When two letters were presented there were stronger effects of exposure duration than when single letters were presented; however, the increased effects of exposure duration seemed to occur principally because he made more confusions between letters at the shorter durations, since he then began either to identify both letters incorrectly, to report three letters as present or to make omissions. These data suggest that, at the shorter exposure durations, there is increased interaction between the target stimuli with consequent impairments on identification performance.

Summary

Our analysis indicates that H.J.A. has impaired visual perceptual processes, despite having some intact perceptual functions (local form discrimination, stereopsis and so forth). He is impaired at the identification of overlapping figures, relative to when the same figures are nonoverlapping; he is poor at discriminating line drawings of real and meaningless stimuli; and his visual identification is strongly affected by the exposure duration of the stimulus. His performance on the object decision task is improved when the stimuli are presented as silhouettes. H.J.A.'s performance with silhouettes suggests that he has global form information available (*see also* Humphreys *et al.,* 1985). His difficulties seem to occur because his global form descriptions are not fully supported by more local form information, so that the segmentation of overlapping figures and the integration of local part information is impaired.

Section 3. Tests of semantic representation

Given the controversy in studies of visual agnosia concerning whether agnosia is due to a perceptual deficit or to difficulties in mapping an intact perceptual information onto semantic descriptions, it is important to examine whether a patient has intact semantic knowledge of the stimuli he or she fails to recognize, since a recognition deficit could be precipitated by a breakdown in semantic knowledge about an object (*see* Warrington, 1975; Warrington and Shallice, 1984).

Experiment 4. Verbal definitions

H.J.A. was asked to give verbal definitions to a series of object names, all corresponding to pictures from the Snodgrass and Vanderwart (1980) picture norms. Thirty-two of the names fell between 0–20 occurrences per million in the Kučera and Francis' (1967) word frequency count and 22 fell between 21 and 274 occurrences per million.

He was able to give detailed definitions of all the objects, irrespective of their name frequency, and his definitions included details of the object's appearance. For example, his definition of a duck was as follows.

> 'This has two meanings. First, the noun version. A duck is a water bird with the ability to swim, fly and walk. It can be wild or kept domestically for eggs; when wild it can be the target of shooting. In the wild it has a wingspan between 15 and 18 inches and weighs about 2 or 3 pounds. Domestic ducks are heavier, up to about 6 pounds perhaps. Wild ducks are multicoloured, mainly brown but with green and yellow breasts. Domestic ducks are white or khaki.
>
> There is also a verb version. Duck is a semislang word implying to lower the body to avoid being struck by a projectile or to avoid striking an obstruction with one's head.'

H.J.A.'s good ability to give verbal definitions suggests that he has intact semantic knowledge about objects. The precise nature of the semantic information he is able to access from vision and from auditory input was examined using a cued definitions test.

Experiment 5. Cued definitions

The task was an extension of the procedure developed by Warrington (1975). H.J.A. was asked a series of increasingly specific questions, following the visual presentation of an object or its name. These questions assessed whether he had sufficient knowledge to distinguish between objects within the same category (*see also* Riddoch and Humphreys, 1987).

The stimuli were 40 line drawings (from Snodgrass and Vanderwart, 1980) or their names, from 5 categories: animals, birds, insects, fruit and vegetables. For each stimulus, a series of up to 11 probe questions were designed to assess both general and specific knowledge about an object (i.e., knowledge about an object's superordinate category vs item-specific knowledge). The specific questions tested stored functional, associational and visual knowledge. For example, for a 'horse', the questions included: can it be kept as a pet? does it eat meat? what colour is it? The objects had no verbal colour associations (*see* Beauvois, 1982; Beauvois and Saillant, 1985). The probe questions were the same for the auditory and visual presentations of the targets, with the exception that H.J.A. was asked the name of the object as a final probe question in the visual presentation condition.

The visual and auditory presentations were given in an ABBA design, with repetitions of stimuli spaced across different test sessions. The probe questions were spoken by the experimenter following the presentation of each target.

For the auditory presentation condition, H.J.A. made 120/120 (100%) correct responses to general knowledge questions and 219/225 (97.3%) correct responses to specific knowledge questions. There was no reliable difference between his performance with general and specific questions ($\chi^2 = 1.84$, $P > 0.05$). For the visual presentation condition, he made 100/120 (83.3%) correct responses to general knowledge questions and 148/225 (65.8%) responses to specific knowledge questions. His performance on both general and specific questions was better with auditory than with visual presentations ($\chi^2 = 17.67$ and 72.39, respectively, both $P < 0.001$). Also, for visual presentations, he performed better on general than on specific questions ($\chi^2 = 11.93$, $P < 0.01$)

H.J.A. has good semantic knowledge of objects when accessed auditorily, but he is impaired at accessing semantic knowledge about the same objects from vision. The deficit in accessing semantic knowledge visually is manifest even with general questions, but it is most evident when the questions probe for semantic information specific to the given object.

It is interesting that H.J.A. was better able to answer questions testing general rather than specific semantic knowledge about the visually presented objects. This could be interpreted as reflecting a general degradation of his visual semantic knowledge about the tested objects, which may selectively impair specific knowledge prior to general category knowledge (*see* Warrington, 1975; Shallice, 1987).

Alternatively, good performance on general questions could reflect an ability to take advantage of visual cues in the stimuli, since such cues should be more relevant to general than to specific questions (Riddoch *et al.*, 1987). If the latter argument holds, then H.J.A. may be relatively good at other probe questions which may be answered using visual cues from the target. Interestingly, H.J.A. was surprisingly good at questions concerning the real-life size or weight of size-normalized drawings of the objects (when asked to judge the real size or weight of objects from Snodgrass and Vanderwart, 1980, relative to a reference object). For instance he made 30/40 (75%) correct weight classifications and named 21/40 (52.5%) of the objects correctly. The mean number of correct weight classifications for age-matching controls was 31.7/40 (79.2%), with a range between 29/40 (72.5%) and 36/40

(90%); their mean range of correct identifications was 35.3/40 (88.25%), range 33–40 (82.5–100%). A similar pattern of performance was found with size classifications, with H.J.A. within the normal range on size classification, while being markedly impaired at object identification.

Warrington (1975) used questions about the real size of objects to assess whether her patients had access to specific semantic knowledge about objects. However, since H.J.A. is otherwise impaired at accessing such knowledge, it appears that his good performance on size and weight judgements reflect the judicious use of visual cues. Indeed, he reported that he was able to classify the weight and size of many animals by judging the size and muscularity of the legs relative to the length of the body. It is important to note that quite accurate judgements may be made on this basis irrespective of whether the subject is able to access specific semantic information about the object. Unfortunately, the same is also likely to be true of other questions in cued definitions tasks addressed to pictorial stimuli (particularly so for the general questions): for this reason, cued definitions tasks might best be regarded as providing information about the kinds of knowledge patients have difficulty accessing (i.e., when patients fail), rather than as providing information about the semantic information to which they have access (i.e., when they succeed).

Summary

H.J.A. has good conceptual information about objects which he cannot recognize visually when he is given their names. He also shows good ability to make use of pictorial cues to answer probe questions, even when there are no signs of correct semantic access for the given object (such as correct identification or an appropriate gesture). It seems quite possible that, in tasks such as cued definitions, H.J.A. is able to use visual cues to compensate for a profound deficit in the normal recognition process.

Section 4. Visual memory

Although H.J.A. is able to give detailed verbal definitions of objects which he fails to identify visually, this may only be considered an assessment of his verbal semantic knowledge of objects; he may still have impaired semantic knowledge about the visual characteristics of objects. Such an impairment may or may not co-occur with a deficit in visual memory. To assess these possibilities, we investigated his ability to draw objects from memory, his memory for colours and his ability to maintain new visual information.

In at least some patients classified as associative agnosic, a disturbance in drawing objects from memory has been observed even when the patient is relatively good at copying (e.g., Levine, 1978; Ratcliff and Newcombe, 1982; but *see* Rubens and Benson, 1971; Wapner *et al.*, 1978). Agnosic patients have also been reported as having poor visual memory (Newcombe and Ratcliff, 1975; Wapner *et al.*, 1978; J.P. Davidoff, J. Wasserstein and B. Wilson, unpublished observations). It is possible that these disturbances, either alone or in combination, could underlie the recognition deficit.

Experiment 6. Drawing from memory

H.J.A. was able to draw from memory objects which he typically failed to recognize from vision. This suggests that he has intact stored knowledge about the appearance of objects. Examples of these drawings are given in fig. 7.

FIG. 7. Examples of H.J.A.'s drawing from memory. H.J.A.'s drawing is on the left; alongside each of his drawings is a drawing from memory carried out by a control subject.

Experiment 7. Stored knowledge about colours

Recently, Beauvois (1982) and Beauvois and Saillant (1985) have presented data indicating that our stored knowledge of verbal colour associations is separate from our stored (visual) knowledge of the colour of objects having no verbal colour associations since, following brain damage, patients may be impaired at retrieving the different forms of colour knowledge from different input modalities. Thus tests of stored colour knowledge need to differentiate between knowledge which is associated verbally with an object and knowledge which reflects the visual properties of the stimulus.

Unfortunately, tests of H.J.A.'s visual colour-related knowledge using at least some of the procedures developed by Beauvois are hampered by his acquired achromatopsia. He now cannot detect letters in the Ishihara charts, and he is impaired at matching colours to sample (where he confuses between dark colours and between light colours, presumably because his matching is based on brightness). This means that it is difficult to use visual tests of colour knowledge. We therefore assessed his colour knowledge by a series of auditory questions concerning the colour of objects with no obvious verbal colour associations (e.g., what is the colour of a frog, a radish, a polar bear, a banana, etc.) or verbal colour associations (e.g., what is the colour associated with a jealous person, a lime, snow, a communist, coal, etc.). He was asked one question at a time and he responded verbally with a colour name. He made 27/30 (90.0%) correct responses to the verbal colour associations and 20/28 (71.33%) correct responses for objects without obvious verbal colour associations. The difference between the tests failed to reach significance ($\chi^2 = 2.15$, $P > 0.05$). H.J.A.'s 3 errors to the verbal colour associations were on questions which required him to assimilate an abstract concept (what is the colour associated with an embarrassed/depressed/afraid person). However, for objects without obvious verbal colour associations, he made some errors which would be surprising were his visual colour knowledge intact (e.g., the colour of an elephant was named as green, that a polar bear, grey). These errors, plus the trend for worse performance on objects without obvious verbal colour associations, suggest that there may be some impairment in accessing stored visual knowledge of colour. Such a result would follow if the mechanisms used for colour perception are also those involved in visual colour memory (*see* Allport, 1985).

Experiment 8. Maintaining visual information

H.J.A.'s ability to maintain new visual information was examined using a letter-match technique (Posner, 1969). He was presented with a pair of letters and asked to respond 'same' if the letters had the same name and otherwise to respond 'different'. On half the trials when the letters had the same name they were also physically identical (e.g., AA), and on the other half the letters with the same name were physically dissimilar (e.g., Aa). Normally, RTs to identical letters (AA) are faster than responses to name-match letters (Aa), providing the interstimulus interval (ISI) is no greater than about 2 s (and the to-be-matched letters are not superimposed; *see* Walker, 1978). The difference between physical (AA) and name (Aa) matches may be attributed to subjects using a visual code to match identical stimuli; however, this visual code decays over time so that the physical-match advantage is typically lost with an ISI of over 2 s.

The apparatus and stimuli were the same as those used in Experiment 3. There were 5 possible letters, A, B, E, G and N, which could be in either upper or lower case. These letters were chosen to minimize the visual similarity between their upper and lower case versions. The to-be-matched letters were either presented simultaneously or with 1 or 2 ISIs: 700 and 1500 ms. H.J.A. initially focused on a central cross, and following a verbal prompt, the first letter was presented (for

500 ms) just below fixation. There was then an ISI, during which the fixation field returned, followed by the second letter, which remained present until he responded. Vocal responses ('same' or 'different'), measured by a voice key which stopped a Birkbeck timer. There were 40 trials at each ISI; 10 physical-match, 10 name-match and 20 different trials. On the different trials, random letters were paired together.

TABLE 5. REACTION TIME (RT, IN MS) AND PERCENTAGE ERROR FOR H.J.A. IN A LETTER-MATCH TEST AT DIFFERENT INTERSTIMULUS INTERVALS (ISI, IN ms)

	Physical match		*Name match*		*Different*	
	RT	*% error*	*RT*	*% error*	*RT*	*% error*
ISI						
0	1004	10.0	1336	20.0	1305	0.0
700	1388	0.0	1508	20.0	1532	0.0
1500	1392	10.0	1554	0.0	1547	5.0

The number correct and the mean RTs (ms) for H.J.A., as a function of the type of match and the ISI, are given in Table 5.

The 'same' RT data were analysed in a 2 × 3 analysis of variance, with the factors being type of match (physical vs name) and ISI (0, 700, 1500 ms), with each RT entered as a separate subject. There were reliable main effects of match type and ISI, F (2,48) = 9.49 and F (1,48) = 10.52, both $P<0.001$. The interaction was not significant, F (2,48 = 1.06, $P>0.05$).

H.J.A. shows a physical match advantage across the three ISIs used; in fact, the size of the advantage appears considerably larger than that normally found, presumably because of H.J.A.'s relatively slow letter identification times. The important finding here is that he seems able to maintain a visual code over at least 1500 ms, quite comparable with that found in normal subjects.

Summary

H.J.A. does not appear impaired either in maintaining new visual information (Experiment 6) or in his stored memory for object shape (Experiment 8). However, there is some indication of an impairment of visual colour knowledge. The data support the interpretation that whilst there may be common mechanisms underlying colour perception and visual colour memory (both impaired in H.J.A.), the mechanisms of perceiving object structure and of memory for object structure seem to be separate (with only the former impaired in H.J.A.).

Section 5. Use of context

To develop models of object recognition, it is crucial to understand how contextual information might be used to facilitate perceptual processing. A case such as H.J.A., who has intact semantic knowledge along with impaired perceptual processing, provides a unique opportunity to examine whether contextual cues can help to override a perceptual deficit. Accordingly, H.J.A.'s use of contextual information was tested by examining his ability to match pictures and words and by examining the effects of a scene context on his object identification.

Experiment 9. Picture-word matching

Pictures were selected from the picture norms of Snodgrass and Vanderwart (1980). On each trial, 4 pictures were presented (in a 2 × 2 format). They were either semantically related (e.g., shirt, coat, blouse, dress) or unrelated (e.g., hair, bed, car, rabbit). Pictures in the semantically related condition also tended to be visually similar. There were 20 trials in each condition. H.J.A. either read a word corresponding to the name of one of the pictures on a trial, or a name was read aloud to him (auditory presentation). He was asked to point to the picture corresponding to the word. The pictures were balanced over the test sessions in an ABBA design.

Given an auditory word prompt, H.J.A. scored 19/20 (95%) in the unrelated condition and 16/20 (80%) in the related condition. With a visual word prompt he scored 20/20 and 16/20 (80%) in the unrelated and related conditions respectively. Taking the data with auditory and visual word prompts together, he performed better in the unrelated than in the related condition (Fisher exact probability, $P=0.013$).

H.J.A. is considerably better at matching pictures to words than he is at identifying the same pictures, indicating that he is able to make use of contextual information. Typically, he reported that when told the name of a picture he was able to retrieve a list of characteristic features of the object which he matched against the pictures. He made errors when there was a close overlap between the features of the target object and those of the distractor; thus confusing a tiger with a zebra, an owl with an eagle, a shirt with a coat, a violin with a guitar, etc. It should be noted that for at least some of the latter instances, he chose the distractor most visually similar to the target rather than another distractor which was either associated with the target or which showed at least as many semantic features (e.g., tiger and lion, shirt and tie, violin and piano). Such errors suggest that it is the visual, rather than the semantic, similarity of targets and distractors which primarily affects his performance.

Experiment 10. Effects of a scene context

The stimuli used were those described in Palmer (1975). They consisted of 20 line drawings of everyday objects normalized for size; 10 of the objects had a visually similar partner amongst the other 10 (e.g., car wheel—record; belt—watch). There were also 20 line drawings of contextual scenes (e.g., a car, a hand carrying a briefcase). Palmer found that such scenes facilitated the tachistoscopic identification of the target objects for normal subjects.

Each line drawing was either presented singly or paired with its matching scene, using an ABBA design across 2 testing sessions. H.J.A. was asked to name the target object in both cases, and the context when it was shown. He named 5/20 (25%) of the line drawings correctly when they were shown in isolation and 14/20 (70%) correctly when they were shown alongside an appropriate context ($\chi^2 = 6.42$, $P < 0.01$). He identified 18/20 (90%) of the contextual scenes correctly (misidentifying a house as a weighing machine and a bathroom as a workshop).

H.J.A. was better at identifying objects when paired with an appropriate context than when shown in isolation. This confirms that he can use semantic information to decide between alternative interpretations of visual input. However, context did not appear to alter his visual processing in any fundamental way; instead, it appeared to influence the responses assigned to the visual descriptions he derived. This is most clearly illustrated by his error responses to line drawings presented alongside a contextual scene. In one test session (conducted subsequently to Experiment 10), the scene context was given along with two visually similar line drawings, one of which was appropriate to the scene. H.J.A. was asked to point to the appropriate object and then to identify it. He made only 8/20 (40%) correct naming responses, which does not differ from his identification of the line drawings in isolation ($\chi^2 = 1.0$). His naming errors reflected an interpretation of the object to fit the scene. For instance, when shown a garage scene and asked to choose between a telephone and a petrol pump, H.J.A. chose the telephone and identified it as an oil can.

GENERAL DISCUSSION

We have documented the case of a patient, H.J.A., with a marked modality-specific deficit in visual object recognition. This deficit appears to be consequent on impaired perceptual processing. H.J.A.'s identification of both line drawings of objects and letters is strongly affected by their exposure duration (Experiment 3), he is relatively impaired at identifying overlapping figures (geometric shapes, letters and line drawings) when compared with when the same figures are shown in adjacent locations (Experiment 1), and he shows no evidence of having intact access to structural knowledge of objects from vision (in an object decision task; Experiment 2a). All of the above difficulties appear to be due to a problem in integrating local form information. For instance, his visual object identification is typically dependent on the use of independent (unintegrated) local feature descriptions, making performance very sensitive to the time available to encode the feature descriptions serially. A failure to integrate local part information with more global shape information will also impair the segmentation of overlapping figures and object decisions where the (meaningless) distractors contain local parts from real objects.

Nevertheless, H.J.A. performs at a high level on some perceptual tasks; he is well able to copy objects he fails to identify and he can match objects across at least some different views (Humphreys and Riddoch, 1984). Further, in contrast to normal subjects, H.J.A. is relatively good at making object decisions to silhouettes

(Experiment 2b). It is important to realize, though, that the perceptual tasks where H.J.A. performs relatively well have in common the property that they do not require integrated form descriptions. Copying may be carried out using local contour tracing and location marking routines (Ullman, 1984), different-view matching may be performed by comparing independent local-part descriptions across viewpoints, and object decisions using silhouettes may be based on undifferentiated global form information. None of the tasks may be considered diagnostic of normal perceptual representation (*see also* Levine, 1978).

With the exception of visual colour memory, H.J.A. appears to have good stored knowledge of objects. He has detailed semantic knowledge about the objects he cannot recognize (Experiments 4 and 5), he is able to draw the objects from memory (Experiment 6) and he can use context to facilitate identification performance (Experiments 9 and 10). Nor is his object recognition deficit due to a poor memory for visual material since he can maintain a visual code for at least 1500 ms (Experiment 8). Thus H.J.A.'s case seems to indicate the effects of a selective input processing deficit along with sparing of other aspects of the object recognition system.

Implications for accounts of visual agnosia: defining integrative agnosia

H.J.A. does not fit easily within the apperceptive-associative classification scheme typically applied to agnosic patients (e.g., Lissauer, 1890; Ratcliff and Newcombe, 1982). His marked visual recognition impairment coexists with accurate copying and good ability to match objects across some different viewpoints. The latter, preserved abilities, might be taken to confirm a diagnosis of associative agnosia (*see* Warrington, 1985). However, unlike at least some agnosics who have difficulty solely in associating perceptual with semantic information (e.g., Riddoch and Humphreys, 1987), H.J.A. appears to have an impaired perceptual representation of the visual world. Further, this perceptual impairment seems specifically to concern integrating local aspects of visual form and linking such information with global aspects of shape. H.J.A. does not have the deficits in processing local aspects of shape (such as contour tracing or orientation discrimination) documented in other patients classified as apperceptive agnosics (Benson and Greenberg, 1969; Campion, 1987).

We therefore propose that the classification scheme for visual agnosia needs to be expanded to accommodate H.J.A., and perhaps other cases which may be demonstrated as tests become more sensitive to the breakdowns which may occur in various substages of visual object recognition (*see* Humphreys and Riddoch, 1987). We suggest that the term integrative agnosia is a suitable description of H.J.A.'s specific problem in grouping local form information. Such a description may be appropriate for all patients with such a selective deficit along with intact discrimination of form elements. It follows that apperceptive and associative agnosia should be viewed solely as umbrella terms covering a number of distinct perceptual disorders.

H.J.A.'s deficit in grouping local form information impairs his visual object recognition. The impairment is not material-specific, and it affects the identification of letters and geometrical shapes as well as objects, given the appropriate presentation conditions. Indeed, it may be that, under normal viewing conditions, letters and geometrical shapes are often identified more easily than objects or line drawings because the former items are simpler and place fewer demands on the perceptual system; that is, in cases such as H.J.A., any effects of stimulus material may be better understood as reflecting quantitative parameters of a single recognition deficit rather than qualitative differences in the way different stimuli are handled. This account can also explain H.J.A.'s better identification of objects from classes with structurally distinct examplars relative to classes with structurally similar exemplars (Section 1). The latter difference cannot be explained by positing a selective loss of stored visual knowledge for particular object classes (*see* Warrington and Shallice, 1984), since H.J.A. can draw from memory exemplars of the categories he finds difficult to recognize visually.

A second implication of the data concerns the argument that visual agnosia may be precipitated by an inability to identify more than one object at a time (i.e. simultanagnosia; Luria, 1959; Kinsbourne and Warrington, 1962). Since there is much evidence to suggest that we normally perceive only one object at a time (in the sense of being able to identify explicitly only one object amongst others concurrently available; Duncan, 1985; Humphreys, 1985), we presume that patients who appear particularly limited in this respect are deficient in switching attention between simultaneously available stimuli (i.e., they have a prolonged refractory period; *see* Levine and Calvanio, 1978). H.J.A.'s dependence on feature-by-feature descriptions for object recognition and the marked effects of exposure duration may be indicative of perceptual processes dependent on an abnormal refractory period. However, the refractory argument cannot provide a sufficient account of the data, since performance should then be normal when there is unlimited exposure time. This was clearly not the case. Further, if the argument were true, then the report of briefly reported stimuli should depend upon whether the stimuli are attended, and random errors should occur for those stimuli outside the focus of attention. We presume here that perceptual identification operates in an all-or-none fashion (*see* Humphreys, 1985). In contrast, H.J.A. made predominantly visually related errors, and this did not vary with the number of targets or the exposure duration (Tables 3 and 4; *see also* Pötzl, 1928; Ranschburg and Schill, 1932; Levine and Calvanio, 1978). Also, although H.J.A. finds two briefly presented letters more difficult to identify than one, his performance decreases to chance at about the same duration for the two conditions. There is little here to suggest qualitative differences between his performance with one and with two stimuli, and the data indicate that in both cases he is operating with partial visual descriptions when he fails to identify stimuli. There is also more direct evidence against the refractory argument, namely, that his RTs to nonoverlapping groups of 2 or 3 stimuli were relatively normal. If H.J.A. were impaired at switching attention we would expect his RTs to be slow when he must attend to individual members of perceptual groups. It seems unlikely that H.J.A.'s feature-by-feature identification processes, vulnerable to the effects of exposure duration, are a function of impaired attentional processes operating on intact perceptual representations.

Other implications concern the relation between H.J.A. and other agnosic patients in the literature. For H.J.A., impaired processes in shape perception seem to coexist with intact stored knowledge of the structural characteristics of objects. This suggests that the deficits in stored structural knowledge of objects which seem to accompany early processing impairments in at least some agnosic patients should be considered as additional to the early processing deficits, which may in isolation produce impaired visual object recognition (e.g., Ratcliff and Newcombe, 1982). Similarly, patients with poor visual memory along with impaired perceptual processing seem to have an additional, and perhaps separate, impairment (e.g., Davidoff and Wilson, 1985).

In other cases, it has been argued that poor stored knowledge of objects is the primary cause of the agnosia (e.g., Warrington, 1975; Warrington and Shallice, 1984). One problem here is that the latter argument rests on an acceptance of the null hypothesis that perceptual processing is intact. A second problem concerns the grounds for arguing that a patient has degraded stored knowledge of stimuli rather than impaired input to that knowledge. Two pieces of evidence typically used for the latter purpose are the consistency of performance (where patients consistently fail on particular stimuli) and the demonstration of a hierarchical breakdown in the recognition process (where the patient shows preserved knowledge of general categorical information about an object relative to his or her knowledge of specific semantic attributes; *see* Warrington and Shallice, 1979, 1984; Shallice, 1987). Interestingly, H.J.A. shows both of the above patterns of performance; he consistently misidentifies certain objects while correctly identifying others and, for the objects he misidentifies, he demonstrates access to general rather than specific semantic knowledge from vision. However, there are good grounds for supposing that H.J.A. has intact stored knowledge about objects, given his drawings from memory and his good cued definition performance when the object's name is presented auditorily. Thus, although there may well be cases where poor stored knowledge of objects underlies visual agnosia, we should be cautious in arguing this only from evidence of a consistent hierarchical breakdown in recognition (*see also* Riddoch *et al.*, 1987).

Implications for theories of visual object recognition

Visual object recognition is a complex process involving a number of distinct operations (*see* Marr, 1982). Recognition could therefore be impaired following disruption to any of these operations. We have proposed that H.J.A. is impaired at integrating local form description and that this impairment precipitates a wide range of perceptual difficulties. This suggests that at least one suboperation involves grouping local form information together, and that this operation is distinct from that of deriving the local form descriptions. Brain damage can affect the former operation while leaving the latter intact.

H.J.A.'s case also demonstrates that at least some of the operations mediating perceptual processing are independent of those underlying our long-term memory of objects (*see* Allport, 1985). This appears to be true of form perception and memory but not perhaps of colour perception and memory.

Finally, we have shown that H.J.A.'s visual object identification is sensitive to the effects of context. However, context influenced H.J.A.'s assignment of responses to stimuli rather than his perceptual processing. Contextual input does not override an early deficit in the integration of visual form.

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APPENDIX

The stimuli from categories with structurally distinct and structurally similar exemplars shown to H.J.A. in Experiment 5, their name frequencies, and whether or not H.J.A. correctly named the item on its first or second presentation.

Objects from categories with structurally distinct exemplars

		Name frequency (occurrences per million)	*First presentation*	*Second presentation*
Bicycle	(vehicle)	5	√	√
Bus	(vehicle)	34	√	√
Bed	(furniture)	127	√	√
Car	(vehicle)	274	√	√
Stool	(furniture)	8	×	√
Table	(furniture)	198	√	√
Chair	(furniture)	66	√	√
Hammer	(tool)	9	√	√
Pliers	(tool)	1	√	√
Fork	(household item)	14	√	√
Nail	(tool)	6	√	√
Cup	(household item)	45	√	√

Objects from categories with structurally similar exemplars

		Name frequency (occurrences per million)	First presentation	Second presentation
Glass	(household item)	99	√	√
Saw	(tool)	352	×	×
Hat	(clothing)	56	√	√
Tie	(clothing)	23	×	×
Coat	(clothing)	43	√	√
Dress	(clothing)	67	×	×
Sock	(clothing)	4	×	×
Shirt	(clothing)	27	√	√
Hair	(body part)	148	×	×
Foot	(body part)	70	√	×
Nose	(body part)	60	×	×
Finger	(body part)	40	×	×
Leg	(body part)	58	×	√
Helicopter	(vehicle)	1	×	
Train	(vehicle)	82	×	
Desk	(furniture)	65	√	
Piano	(furniture)	38	√	
Axe	(tool)	12	√	
Knife	(household item)	76	√	
Spoon	(household item)	6	√	
Shoe	(clothing)	14	√	
Skirt	(clothing)	21	×	
Glove	(clothing)	9	√	
Cap	(clothing)	27	×	
Hand	(body part)	431	√	
Arm	(body part)	94	√	
Lips	(body part)	69	×	
Ear	(body part)	29	×	
Camel	(animal)	1	√	√
Bear	(animal)	57	×	×
Sheep	(animal)	23	×	×
Chicken	(bird)	37	√	√
Lion	(animal)	17	√	√
Squirrel	(animal)	1	√	√
Goat	(animal)	6	×	×
Tiger	(animal)	7	×	×
Bee	(insect)	11	×	×
Butterfly	(insect)	2	√	×
Duck	(bird)	9	×	√
Mouse	(animal)	10	×	×
Rabbit	(animal)	11	×	×
Deer	(animal)	13	√	√
Spider	(insect)	2	×	×
Ant	(insect)	6	×	×
Fox	(animal)	13	√	×
Eagle	(bird)	5	×	×
Apple	(fruit)	9	√	√
Pear	(fruit)	6	√	√
Potato	(vegetable)	15	×	×
Onion	(vegetable)	15	×	×
Celery	(vegetable)	4	×	×
Orange	(fruit)	23	×	×
Lettuce	(vegetable)	—	×	×
Donkey	(animal)	1	×	
Zebra	(animal)	1	×	
Swan	(bird)	3	√	

Objects from categories with structurally similar exemplars

		Name frequency (occurrences per million)	*First presentation*	*Second presentation*
Owl	(bird)	2	×	
Cow	(animal)	29	√	
Horse	(animal)	117	×	
Caterpillar	(insect)	1	√	
Lemon	(fruit)	18	×	
Carrot	(vegetable)	1	×	
Banana	(fruit)	4	×	

H.J.A.'s superior naming of objects from categories with structurally distinct exemplars relative to his naming of objects from categories with structurally similar exemplars, cannot easily be attributed to factors other than structural similarity. He shows no effects of name frequency on picture identification, so differences in name frequency between the categories cannot account for his performance. Also, his performance cannot be attributed to particular difficulties with animate objects or with objects whose individual names do not correspond to their 'base-level' representations (e.g., Rosch, 1975). Whereas most of the 'structurally distinct' items are inanimate, this classification does not hold for all the items (e.g., 'body parts' is a 'structurally distinct', animate category). Also, while some of the 'structurally similar' items have base-level representations corresponding to their category names (e.g., birds, insects), this does not hold for animals, fruits or vegetables.