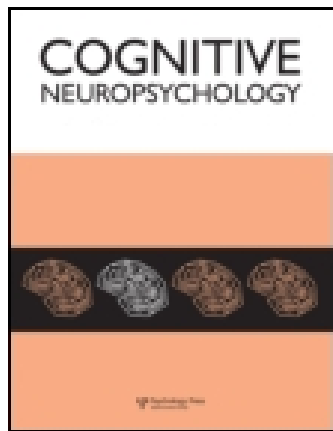


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A tale of two agnosias: Distinctions between form and integrative agnosia

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A tale of two agnosias: Distinctions between form and integrative agnosia

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The performance of two patients with visual agnosia was compared across a number of tests examining visual processing. The patients were distinguished by having dorsal and medial ventral extrastriate lesions. While inanimate objects were disadvantaged for the patient with a dorsal extrastriate lesion, animate items are disadvantaged for the patient with the medial ventral extrastriate lesion. The patients also showed contrasting patterns of performance on the Navon Test: The patient with a dorsal extrastriate lesion demonstrated a local bias while the patient with a medial ventral extrastriate lesion had a global bias. We propose that the dorsal and medial ventral visual pathways may be characterized at an extrastriate level by differences in local relative to more global visual processing and that this can link to visually based category-specific deficits in processing.

Keywords: Apperceptive agnosia; Form agnosia; Local/global processing; Extrastriate lesions.

Agnosia¹ was first described by Lissauer (1890) as a modality-specific disorder of visual recognition (which cannot be attributed to poor sensory processing such as impaired acuity, reduced visual fields, or deficits in colour, movement, or depth perception). Lissauer distinguished between apperceptive agnosia (impairment in perceptual processing) and associative agnosia (impairment either in accessing stored memories of visual

concepts, or a deficit with the concepts themselves). Over the last 20 years or so these two broad categories of deficit have been fractionated, and behaviourally different subtypes of apperceptive and associative agnosia have been identified. We focus here on subtypes of apperceptive agnosia.

Traditionally two simple clinical tests have been used to establish the integrity of apperceptive

¹This term was originally coined by Freud (1891).

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processes: shape discrimination and shape copying (for a discussion see Riddoch & Humphreys, 2003). A patient failing these tasks would be classified as suffering from apperceptive agnosia, while patients who succeeded would be classed as having associative agnosia. A number of early cases were described that conformed to these distinctions: for apperceptive agnosia, Efron's patient, Mr. S. (Efron, 1968); for associative agnosia Riddoch and Humphreys's patient J.B. (Riddoch & Humphreys, 1987b). However, in 1987, Riddoch and Humphreys described a case of apperceptive agnosia (H.J.A.) who succeeded well on shape discrimination and shape-copying tasks, but who failed on more stringent tests of visual perception (such as distinguishing the individual items in an overlapping figures test, or detecting targets embedded in displays of homogeneous distractors (Riddoch & Humphreys, 1987a). Riddoch and Humphreys argued that H.J.A. had impaired perceptual integration of shape elements into perceptual wholes, a disorder they termed integrative agnosia. Patients with a similar pattern of spared and impaired abilities have since been reported in the literature (Amicuzi et al., 2006; Behrmann & Kimchi, 2003; Butter & Trobe, 1994; De Renzi & Lucchelli, 1993; Grossman, Galetta, & D'Esposito, 1997). Indeed, it seems likely that Lissauer's original case, G.L., may also fall within this group (for a discussion on this, see Riddoch & Humphreys, 2003). Such patients may be distinguished from cases where shape discrimination and copying abilities are severely impaired, a disorder we label as form agnosia (Adler, 1944; Benson & Greenberg, 1969; Campion & Latto, 1985; Davidoff & Warrington, 1993; Efron, 1968; Milner et al., 1991; Vecera & Behrmann, 1997). Form agnosia, as a concept, is not uncontroversial; Warrington and co-workers have argued that visual sensory processing can only be considered intact if the patient is able to detect "differences between non-representational patterns" (Warrington & Rudge, 1995, p. 174) and that patients with form agnosia are best described as "pseudo-agnosics". Against this, studies have

been performed where low-level visual processes have been stringently assessed and have been found to be normal in patients with disorders of this type (e.g., De Haan, Heywood, Young, Edelstyn, & Newcombe, 1995; Efron, 1968; Milner et al., 1991). Farah (1990) argued that patients where a perceptual processing problem underlay a visual recognition deficit formed a very heterogeneous group. She used the term "apperceptive agnosia" in a "narrow sense" to refer to patients with form agnosia, as these formed a relatively homogeneous subgroup. More recently, she has acknowledged that form agnosia is the more generally accepted label, being first proposed by Benson and Greenberg (1969; also Farah, 2004).

One of the problems inherent in reports of single cases of patients with visual agnosia is that there is little consistency in the diagnostic tests used. A further problem is that until recently, it has not been possible to accurately pinpoint areas of damage in such patients. However, as more cases are reported, some consistency in the areas of damage is revealed. Most of the documented cases of form agnosia have suffered carbon monoxide poisoning (e.g., Adler, 1944; Benson & Greenberg, 1969; Campion & Latto, 1985; Efron, 1968; Milner et al., 1991); two exceptions are S.M.K. who suffered anoxia following an assault (Davidoff & Warrington, 1993) and J.W. who suffered anoxic encephalopathy following a cardiac event (Vecera & Behrmann, 1997). In general, patterns of diffuse damage have been reported. Recently James et al. (James, Culham, Humphrey, Milner, & Goodale, 2003), from high-resolution structural magnetic resonance imaging (MRI), showed that one form agnostic, D.F. (see Milner et al., 1991), has severe bilateral damage to the ventral lateral occipital complex (slightly worse on the right than on the left). The primary visual cortices and the fusiform gyri were spared. There was additional tissue lost in the intraparietal sulcus and evidence of generalized atrophy. In the case of J.W., Vecera and Behrmann (1997) report multiple hypodensities in both occipital lobes and in the right parietal area, based on computed tomography (CT) scan.

Lesion information is also available for patients with integrative agnosia. Cases here have been reported following stroke (e.g., Grossman et al., 1997; Riddoch, Humphreys, Gannon, Blott, & Jones, 1999; Shelton, Bowers, Duara, & Heilman, 1994); traumatic brain injury (Delvenne, Seron, Coyette, & Rossion, 2004; De Renzi & Lucchelli, 1993; Marotta, Genovese, & Behrmann, 2001; Ricci, Vaishnavi, & Chatterjee, 1999), Alzheimer's disease (Grossman et al., 1997), an anoxic episode following myocardial infarction (Behrmann & Kimchi, 2003; Marotta, McKeef, & Behrmann, 2002), and progressive multifocal leukoencephalopathy (PML; Butter & Trobe, 1994). A developmental case has also been reported (Amicuzi et al., 2006). In all instances resulting from stroke, bilateral posterior lesions are again reported. MRI scans for H.J.A. show bilateral lesions of medial ventral occipito-temporal regions, including inferior temporal gyrus, the fusiform gyrus, and the lingual gyrus (see Figure 1 here, also Allen, Humphreys, & Bridge, 2007; Riddoch et al., 1999). Lesion information for patient L.W.T. (Shelton et al., 1994) appears similar (on CT scan, the lesion was localized to the inferior temporal lobes bilaterally involving the temporal, fusiform, and lingual gyri). For patient S.Z. (Grossman et al., 1997), the lesion affected the middle and inferotemporal cortices and spared the primary visual cortex. The right occipito-temporal region is implicated in one of the four cases with traumatic brain injury (e.g., De Renzi & Lucchelli, 1993; Marotta et al., 2001); a further case had bilateral occipito-temporal lesions (Delvenne et al., 2004); and for one case, no abnormalities were shown on the MRI scan (Ricci et al., 1999). However, it should also be noted that the anoxic patient (R.N.) had bilateral parieto-temporal lesions (Behrmann & Kimchi, 2003; Marotta et al., 2002), the developmental case had bilateral occipito-temporo-parietal lesions (Amicuzi et al., 2006), and the case with PML also demonstrated bilateral occipito-temporal lesions on MRI (Butter & Trobe, 1994). In summary, cases with integrative agnosia appear to have more medial ventral lesions than do patients with form

agnosia, with the lesions also tending to encroach into the posterior temporal lobes, but the picture is not completely uniform.

These conclusions are limited by the lack of direct comparisons between patients, in terms of both the scanning protocols and the functional tests being administered. In the present paper we aim to remedy this by reporting experimental and imaging data that enable a direct comparison to be made between a patient with form agnosia and an integrative agnosic patient. The cases (S.A. and H.J.A.) both present with bilateral occipital lesions, but the lesions involve dorsal extrastriate cortex in the case of form agnosic (S.A.) and medial ventral extrastriate cortex in the case of integrative agnosia (H.J.A.). The patients also differ functionally. S.A., the form agnosic, shows better identification of animate than inanimate items and a tendency to process visual stimuli at a local rather than a global level. H.J.A., the integrative agnosic, is better able to identify inanimate than animate items and shows a tendency to process visual stimuli initially at a global rather than a local level. We discuss the implications of these results for theories of visual object processing and for understanding perceptual variants of category-specific disorders.

The data are reported in two sections, following case reports of high-resolution structural MRIs. The aim of the experiments was to demonstrate differences in the visual-processing consequent on the different lesions. In the first section (Section A) we report data that (a) classify both patients as agnosic, (b) demonstrate that both patients have perceptual deficits, but that (c) the two patients diverge on tests of shape perception, resulting in a diagnosis of form agnosia for S.A. and integrative agnosia for H.J.A. In Section B, we report experimental data on other perceptual abilities in the patients, including figure-ground coding, the use of top-down knowledge, curve tracing, and the perception of hierarchical stimuli. Perceptual differences between the patients are documented in each case. We review the implications for theories of object recognition in the General Discussion.

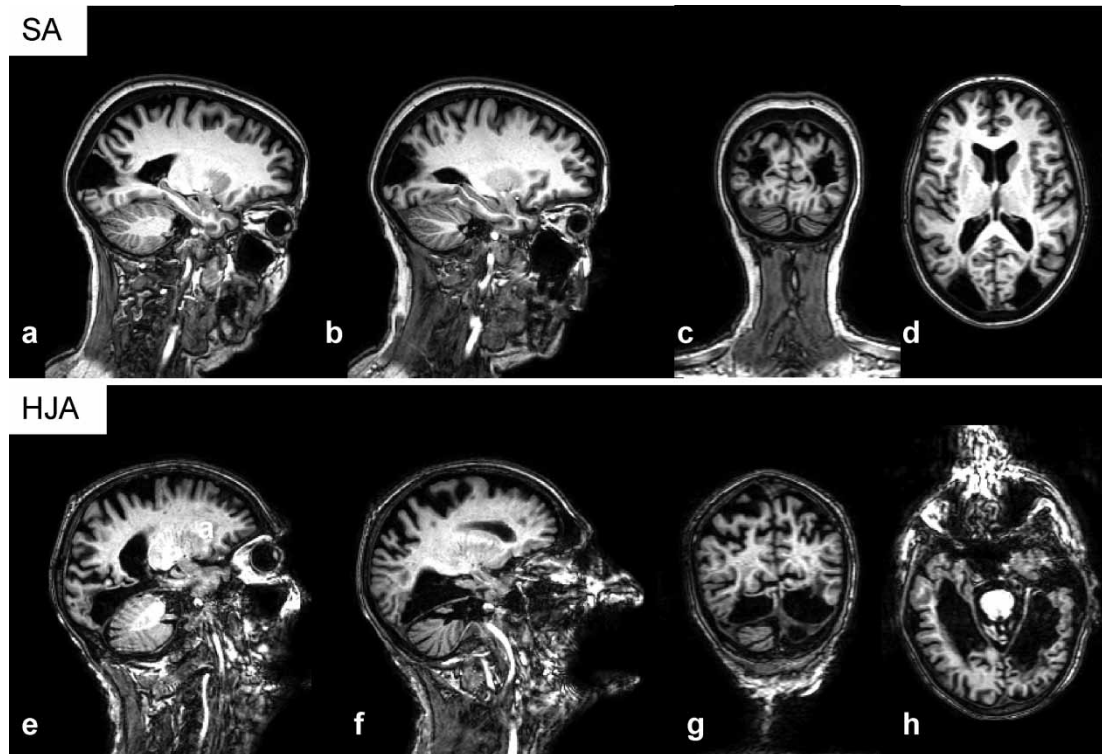


Figure 1. (a)–(d): Functional magnetic resonance imaging (fMRI) showing a dorsal extrastriate lesion (S.A.). (e)–(h): fMRI showing a ventral extrastriate lesion (H.J.A.).

SECTION A: DEFINING THE TYPE OF AGNOSIA

Case histories

S.A. S.A., a hospital clerical worker, suffered a bilateral occipital stroke in 1997 at the age of 50 years. She attended for testing 4 years post-lesion, in 2001. Figure 1 presents the results from a high-resolution (3T) structural scan (1 mm isotropic) performed in February 2006.

This revealed a sparing of the calcarine cortex (although there was some involvement on the left) and the ventral extrastriate areas (including the lingual and fusiform gyri). The lesion involved the dorsal extrastriate cortex, including the right intraparietal sulcus. Areas MT, LOC, PEF, and V4 were spared (see Figure 1b). S.A. lived with her husband and had an independent life,

including a part-time clerical job. She self-reported with some difficulties in object recognition and reading. Her colour naming was relatively spared. There was some impairment in face recognition. She scored 38/54 on the Benton Face Recognition Test (Benton, Hamsher, Varney, & Spreen, 1983), thus falling into the “moderately impaired class”. On the Warrington Recognition Test (Warrington, 1984) she scored 34/50 for faces and 46/50 for words. Age-matched control scores are 42.7 ($SD = 3.8$) for faces and 43.2 ($SD = 4.0$) for words (from the Warrington Recognition Test manual). S.A.’s recognition memory for faces is therefore impaired relative to that for words.

H.J.A. H.J.A. was aged 82 years at the time of the present investigations. He had suffered a posterior

cerebral artery stroke perioperatively in 1981 resulting in a dense visual agnosia, prosopagnosia, alexia without agraphia, achromatopsia, and topographical impairments. Neurological and psychological investigations have been reported in detail previously (Boutsen & Humphreys, 2002; Humphreys & Riddoch, 1984, 1987b; Riddoch & Humphreys, 1987a; Riddoch et al., 1999). The stroke resulted in bilateral lesions of the occipital lobe, extending anteriorly towards the temporal lobes. Figure 1 presents the results from an MRI scan using the same protocol as that for S.A. conducted in 2005. This shows bilateral lesions of the inferior temporal gyrus, the occipitotemporal gyrus, the fusiform gyrus, and the lingual gyrus; ventral V2, V3, and V4 were likely to be included. The stroke did not impinge on the parietal lobes. There was also some age-related atrophy in this scan, mostly in superior parietal regions. H.J.A.'s residual visual abilities have remained relatively constant since his initial lesion, although there is evidence of a loss of stored visual knowledge about particular objects (Riddoch et al., 1999). H.J.A. had markedly poor visual recognition affecting objects from all categories, but being most pronounced with animate objects (Humphreys & Riddoch, 1984, 1987b; Riddoch & Humphreys, 1987a; Riddoch et al., 1999; see also Section B here). H.J.A. continues to be largely independent in everyday life, although he lives in sheltered accommodation.

Demonstrating visual agnosia

The characteristic feature of visual agnosia is the impaired ability to recognize visually presented objects. H.J.A.'s object recognition difficulties have been documented previously (e.g., Humphreys & Quinlan, 1987; Riddoch & Humphreys, 1987a; Riddoch et al., 1999), and further tests of picture naming are reported here. S.A.'s object recognition was initially assessed using a computerized version of the Snodgrass and Vanderwart (1980) cohort of line drawings (pictures were presented with unlimited durations using E-Prime software, Psychological Software Tools, Pittsburgh, PA). Naming data were

scored for accuracy. S.A. scored 155/260 (59.6%), whereas H.J.A. scored only 48/260 (18.5%) correct. As a control, using the same presentation conditions, S.A.'s husband (K.A.) scored 236/260 (90.8%). S.A.'s performance was clearly worse in this case, $\chi^2(1) = 146.2$, $p < .0001$. S.A.'s errors were "don't know" (67/105, 63.8%), visual/semantic (29/105, 25.7%; e.g., mouse \rightarrow squirrel), or visual (6/105, 5.7%; e.g., sock \rightarrow banana). A small percentage of errors involved giving the superordinate name (2/105, 1.9% items), or an unrelated response (1/105, cherry \rightarrow rabbit). With these stimuli, H.J.A. tended to make more errors when naming animate than inanimate items (10.7% vs. 22.2% correct; Fisher's Exact Test, $p < .05$). K.A. showed a similar pattern of performance to that of H.J.A. (85.5% vs. 90.5% correct for animate and inanimate items, respectively). However, the patterns of performance for S.A. were similar for both sets of items (60.2% and 59.6% correct for animate and inanimate items, respectively). S.A. gave no evidence of knowing the identity of objects that she was unable to name. H.J.A. made 36.3% "don't know" responses (77/212), 27.4% visual (58/212), 26.9% visual/semantic (57/212), 10/212 superordinate, and 10/212 unrelated errors.

In an additional test of object naming, S.A., H.J.A., and K.A. (as a control) were given a subset of stimuli from Riddoch and Humphreys (2004). These stimuli were full coloured images of objects that could be identified from their outline shapes (by controls; see Riddoch & Humphreys, 2004). There were 15 animate and 15 inanimate items. The stimuli were standardized for size (their longest dimension was 4.5 inches [11.4 cm]) and were presented for 200 ms using E-Prime at the centre of a computer screen, viewed from 50 cm. S.A. named 10/15 animate and 3/15 inanimate items. Her errors were mostly "don't know" responses ($N = 8$) plus either visual-semantic ($N = 6$) or visual errors ($N = 3$). H.J.A. named 5/15 animate and 11/15 inanimate items. His errors were visual-semantic ($N = 10$) or visual ($N = 4$). K.A. performed at ceiling (30/30 correct). Binary logistic regression

using the backward method revealed significant effects for patient (with H.J.A. naming more items overall than S.A.) and animacy (more animate items were named than inanimate items). There was also an interaction between patient and animacy, which indicated that H.J.A. performed better with inanimate items than with animate items, $\chi^2(1) = 4.8, p < .03$, while the reverse was true for S.A., $\chi^2(1) = 6.7, p < .01$. The output from the analysis is given in Table 1.

When given the names of the objects afterwards, both patients were able to provide accurate definitions of the stimuli, indicating that the problems did not arise at a conceptual level. Though Riddoch et al. (1999) report that H.J.A. suffered some loss of visual knowledge, this was not evident for the items presented here.

These data indicate that both S.A. and H.J.A. are impaired at object recognition compared with control performance. S.A. performed better than H.J.A. with unlimited presentation times but this advantage decreased with briefer exposures (also see below). Also, while S.A. showed no difference between animate and inanimate items with unlimited exposures, she was better with inanimate items when presentation times were limited (again see below); H.J.A. was better at identifying inanimate than animate items at both exposures. The patients made predominantly visual-semantic or visual errors (or “don’t know” responses for S.A.), indicating that the problem

was one of recognition rather than name retrieval. Also the patients were able to give accurate definitions to the names of objects, suggesting no deficit at a conceptual level. These naming data conform to a pattern of visual agnosia.

The perceptual locus of the deficit

A diagnosis of apperceptive agnosia is made when patients with impaired visual naming show impairments in perceptual processing and have no accompanying deficit in semantic knowledge. In 1987 we demonstrated that H.J.A.’s picture-naming ability was abnormally reduced if stimuli were presented at reduced exposures, consistent with an underlying perceptual deficit (Riddoch & Humphreys, 1987a; Riddoch et al., 1999). For instance, identification for one set of drawings decreased from 80% to 45%, 40%, and 15% correct at unlimited, 1,000-ms, 500-ms, and 100-ms exposure durations, respectively. We also explored the effects of manipulating exposure duration with S.A. She was asked to name a subset of the Snodgrass and Vanderwart (1980) line drawings. There were 76 stimuli made up of 38 animate and 38 inanimate items, half with high and half with low name frequencies. There were five different exposure durations: 1,000 ms, 500 ms, 250 ms, 100 ms, and 50 ms. Each set was presented in a different test session at 4-weekly intervals. Like H.J.A., S.A.’s naming

Table 1. Logistic regression output for S.A. and H.J.A.’s picture-naming data

| Step 1 ^a | B | SE | Wald | df | Sig. | Exp(B) |
|---------------------|---------|-------|--------|----|------|--------|
| Category | - 1.705 | 0.801 | 4.534 | 1 | .033 | 0.182 |
| Patient | - 2.398 | 0.870 | 7.590 | 1 | .006 | 0.091 |
| Category × Patient | 3.784 | 1.165 | 10.548 | 1 | .001 | 44.000 |
| Constant | 1.012 | 0.584 | 3.002 | 1 | .083 | 2.750 |

Note: Hosmer and Lemeshow Goodness of Fit Test, $\chi^2(2) = 0.0, p > .05$. The final step of the SPSS output for binary logistic regression is reported. The Wald statistic uses the estimated regression coefficients (B) and their standard errors (SE) to compute a chi-square distribution. Exp(B) is an indicator of the change in odds resulting from a unit change in the predictor. The backward method of regression has been used. The Hosmer–Lemeshow goodness-of-fit statistic has been used to assess how well the chosen model fits the data. This method of reporting the output of the binary logistic regression is recommended by Field (2005).

^aVariable(s) entered on Step 1: Category, Patient, Category × Patient.

Table 2. Number of items identified by S.A. at different exposure durations

| Exposure duration ^a | Living things | | Artefacts | | Total |
|--------------------------------|---------------|----------|-----------|-----------|-----------|
| | HF | LF | HF | LF | |
| 1,000 | 17 (89.5) | 19 (100) | 17 (89.5) | 19 (100) | 72 (94.7) |
| 500 | 17 (89.5) | 19 (100) | 19 (100) | 16 (79.8) | 70 (93.4) |
| 250 | 9 (47.4) | 8 (42.1) | 14 (73.9) | 8 (42.1) | 39 (51.3) |
| 100 | 9 (47.4) | 5 (26.3) | 5 (26.3) | 2 (10.5) | 21 (27.6) |
| 50 | 2 (10.5) | 4 (21.1) | 2 (10.5) | 0 (0) | 8 (10.5) |

Note: Percentages in parentheses. HF = high frequency. LF = low frequency.

^aIn ms.

performance was affected by the reduction in exposure duration, particularly at the shorter exposure durations. The percentage correct at each exposure is shown in Table 2. K.A., given the stimuli at the same exposures, showed no deterioration in performance.

Although overall there was not much difference in the naming of animate and inanimate items (57.4% vs. 53.7% correct, respectively), at short exposures S.A. showed a clear advantage for animate items. The trend became more exaggerated if the responses to the shorter two exposures only were taken: 26.3% and 11.8% correct for living and nonliving items, respectively; see Table 1, $\chi^2(1) = 5.12$, $p < .02$. The deficit for inanimate items, here, cannot be linked to S.A. making better use of colour information for animate items, since only black and white line drawings were used.

These data show that picture naming is abnormally impaired for S.A., like H.J.A., under conditions where perceptual processing is stressed. This provides evidence for a perceptual locus for the deficit. When given the names of objects used in these tests, S.A. was able to provide an adequate definition in all 76 cases. Thus, there was no evidence for a semantic component to the deficit, along with positive evidence for a perceptual contribution (an abnormally increased effect of exposure duration). Riddoch and Humphreys (1987a; Riddoch et al., 1999) also reported evidence on the sparing of semantic knowledge in

H.J.A. Thus, for both cases, the data indicate a perceptual rather than a semantic locus to the deficit—apperception is impaired.

Further tests were administered to examine low-level perceptual processing. S.A.'s performance is contrasted here with published data from H.J.A. S.A.'s judgements of similarities and differences in line length, line orientation, circle size, position of a gap in a circle circumference, and angle size were assessed. The first four of these were examined using subtests from BORB (Birmingham Object Recognition Battery, Riddoch & Humphreys, 1993). There were equal numbers of "same" and "different" trials ($N = 15$ for all subtests except for the position of gap where $N = 20$). S.A. performed each test three times. On the first two occasions stimuli were presented side by side, and on the third occasion stimuli were presented one above the other. On the second occasion when stimuli were presented side by side S.A. was allowed to trace the items with her finger. There was no significant difference in the scores collapsed across the four tests on the three different occasions of testing, $\chi^2(2) = 4.9$, $p > .05$. The data were therefore averaged across the three occasions of testing. H.J.A. performed similar tests on one occasion only (see Humphreys & Riddoch, 1984), and his data are presented here for comparison (see Table 3).

The scores for both patients fell within the control range on all the low-level perceptual tests in BORB.²

²However, we note that S.A. was at the low end of the control range on the position of the gap task.

Table 3. *S.A. and H.J.A.'s matching performance for basic properties of visual stimuli*

| | <i>Match</i> | | | |
|---------------|-----------------------------------|---------------------------------|--|--|
| | <i>Length</i> (<i>N</i> = 30) | <i>Size</i> (<i>N</i> = 30) | <i>Orientation</i> (<i>N</i> = 30) | <i>Position of gap</i> (<i>N</i> = 40) |
| S.A. | 23.7 | 24.3 | 23.3 | 25 |
| H.J.A. | 25 | 23 | 26 | 38 |
| Control mean | 26.9 (1.6) | 27.3 (2.4) | 24.8 (2.6) | 35.1 (4.0) |
| Control range | 22–30 | 18–30 | 18–29 | 24–29 |

Note: Items from the Birmingham Object Recognition Battery (BORB) test battery; Riddoch and Humphreys, 1993. The numbers of correct trials are shown. Standard deviations in parentheses.

We also measured acuity and contrast sensitivity functions for the patients, using sine wave gratings varying in spatial frequency. S.A. was compared with K.A., and both were tested using the method of adjustment. Measurements were taken at two viewing distances (47 and 190 cm). H.J.A. was tested using a forced-choice staircase procedure. The data are shown in Figure 2. The results suggest that both H.J.A. and S.A. had decreased sensitivity, especially for higher contrast sensitivities (however, the relations between contrast sensitivity functions and performance with suprathreshold stimuli as reported through the rest of the paper is far from clear). Snellen acuity, with correction, was normal for both cases (6/6).

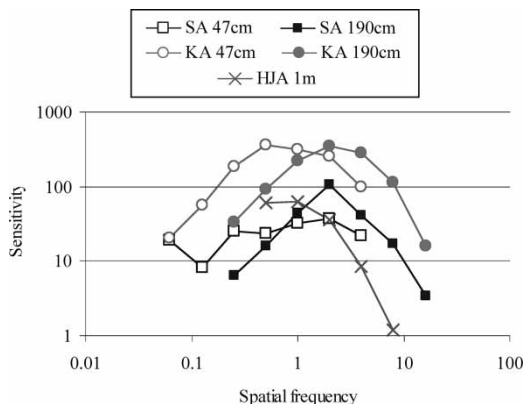


Figure 2. *Contrast sensitivity functions for S.A., H.J.A., and K.A. (control). Measurements for S.A. and K.A. were performed at two viewing distances (47 and 190 cm). The viewing distance for H.J.A. was 1 m.*

Distinguishing form agnosia and integrative agnosia

A standard test of form perception, where patients with form agnosia have consistently been shown to be impaired, is the Efron shape test (Efron, 1968). Interestingly, Humphreys et al. (1992) reported that H.J.A. had intact performance on this task, suggesting that his level of deficit occurred at a level of processing after simple form coding had been achieved. Consequently we evaluated S.A.'s performance on the Efron shape test. We also re-evaluated H.J.A. Subsequently we examined form processing using simple copying tasks and tests of figure-ground segmentation.

The Efron shape test

The test used here was similar to that described by Efron (1968) and involved judging whether a 2D shape was a rectangle or a square. There were 50 trials in total, with an equal number of squares and rectangles. All items were presented as black outlines on a white background. Squares were 1 in. × 1 in. There were five grades of difficulty with the rectangles. The vertical sides were always 1 in.; the horizontal edges were 1.025, 1.25, 1.5, 1.75, and 2 in. There were 5 trials for each of the different rectangle sizes. S.A. performed the test on two separate occasions scoring 37/50 on both occasions. She never made errors in judging the square (100% correct on both occasions). On "rectangle" trials, she performed particularly poorly with the rectangles that were closest in size to the square (0/10 on both test

occasions). She scored 10/10 on the easiest discrimination, 9/10 for the next easiest, and 5/10 for the intermediate discrimination. H.J.A. performed at ceiling on this task (100% correct). Ten controls (mean age 66.2 years, $SD = 6.8$) scored an average of 46.9/50 ($SD = 3.6$) on this

task; S.A.'s score fell more than 2 standard deviations below the control mean.

Copying

Examples of the copies produced by H.J.A. and S.A. are shown in Figure 3. Copies of simple

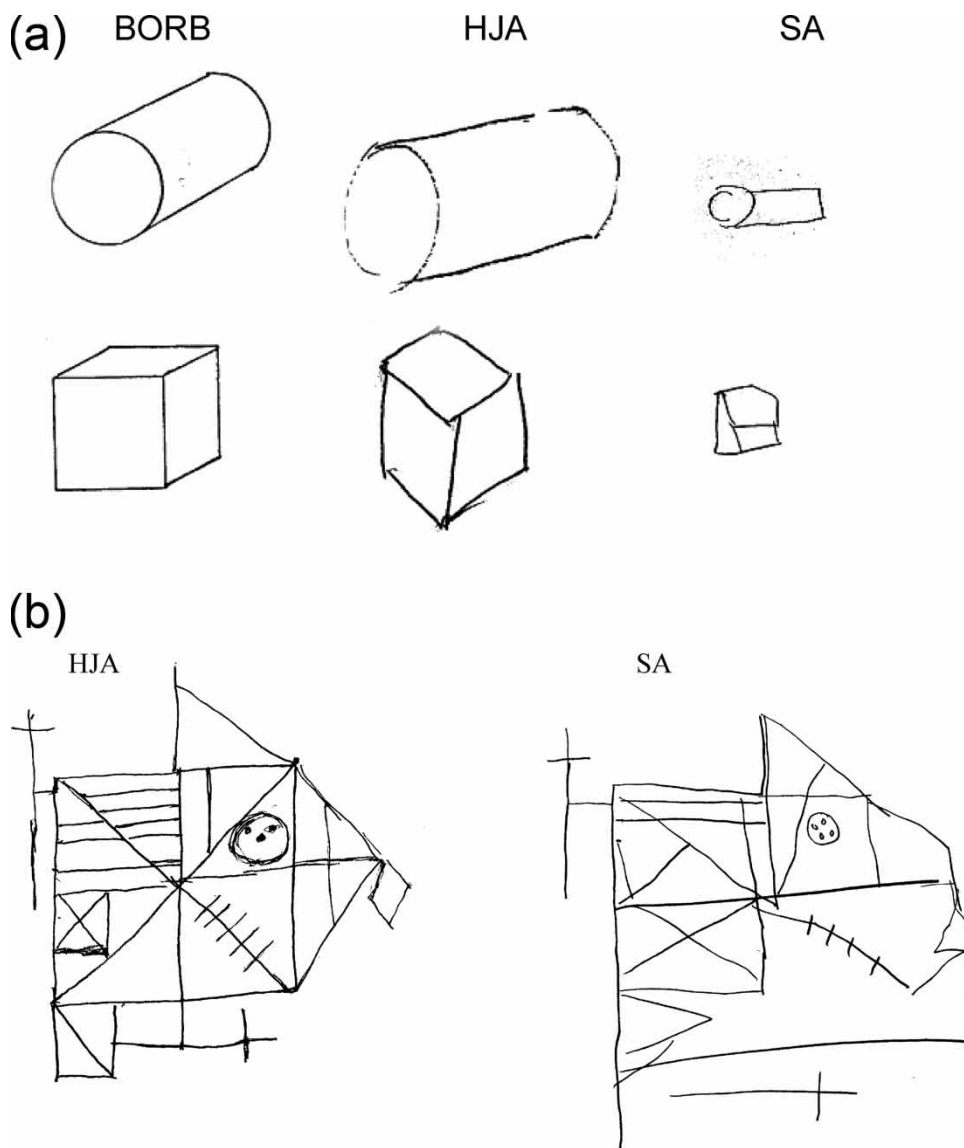


Figure 3. Illustrations of copying performance. (a) On the left are examples of a cube and a cylinder from the Birmingham Object Recognition Battery (Riddoch & Humphreys, 1993). In the centre and to the right, respectively, are H.J.A.'s and S.A.'s copies. (b) H.J.A.'s (left) and S.A.'s (right) copies of the Rey-Osterrieth Figure.

geometric shapes taken from the BORB (Riddoch & Humphreys, 1993) are shown in Figure 3a. Target stimuli are shown on the left. H.J.A.'s copies are relatively accurate and are similar (or slightly larger) in size to the target stimuli. While asked to produce copies similar in size, S.A.'s productions were much smaller than the originals, and her accuracy was poor. Both patients were asked to copy a more complex stimulus (the Rey–Osterrieth Figure; Meyers & Meyers, 1995; see Figure 3b). While some inaccuracy was shown by both patients, this was particularly pronounced for S.A. Both H.J.A.'s and S.A.'s reproductions of the Rey Figure were submitted to 15 raters who were asked to grade the accuracy of the copies relative to the original. A scale of 1–10 was used with 10 being a perfect score. H.J.A. obtained a mean score of 7.8 ($SD = 1.3$) and S.A. a mean score of 5.2 ($SD = 2.0$). The difference in ratings scores was significant (sign test exact significance, $p < .0001$).

Figure–ground segmentation

Shape judgement (Visual Object and Space Perception Battery, VOSP). A basic examination of figure–ground segmentation was provided by the shape detection test from VOSP (the Visual Object and Space Perception Battery; Warrington & James, 1991). Participants are asked to detect an X (which may be either present or absent) in the presence of background noise. Performance can be based on local pooling of luminance. Both patients performed within the normal range. S.A. scored 18/20 (control score = 19.9, range = 18–20), and H.J.A. scored 20/20 (100% correct) on this task. Basic aspects of figure–ground performance were performed reasonably well.

Overlapping Figures Test. To test figure–ground segmentation based on edge cues, the patients performed the Overlapping Figures Test from BORB (Riddoch & Humphreys, 1993). S.A. showed a ratio of 1 : 1.4 in her naming times to pairs of non-overlapping and overlapping letters, and this ratio increased to 1 : 1.8 for triplets of letters. The control mean was 1 : 1 for both pairs and triplets of letters (as provided in BORB).

As previously reported, H.J.A. also found it difficult to identify letters in the overlapping relative to the nonoverlapping conditions. His ratio for paired nonoverlapping to paired overlapping was 1.0 : 2.0 and for the same conditions with triplets of letters was 1.0 : 1.7 (see Riddoch et al., 1999). Thus, relative to the controls, both S.A. and H.J.A. were impaired in performance in the overlapping relative to the nonoverlapping condition.

Discussion

Both S.A. and H.J.A. were impaired in naming visually presented objects. Although both patients showed some spared perceptual abilities (e.g., when required to match basic visual features), both demonstrated perceptual impairments. Both patients were abnormally affected by decreasing the exposure duration, and both were impaired at tests of figure–ground perception dependent on the segmentation of overlapping letters. Furthermore, both patients had good semantic knowledge about the objects they failed to recognize as line drawings (see Riddoch & Humphreys, 1987a; Riddoch et al., 1999, for additional data on H.J.A.). These data indicate that both patients have apperceptive agnosia. However, alongside these similarities, the patients also clearly differed. In particular, H.J.A. performed at control level in the Efron shape-matching test whilst S.A. was impaired. In addition, H.J.A. showed accurate copies of even complex stimuli, whilst S.A.'s drawings were often inaccurate. S.A.'s impairments at the Efron shape test and copying are characteristic of form agnosics, who seem impaired at coding basic aspects of form (see Adler, 1944; Behrmann & Kimchi, 2003; Benson & Greenberg, 1969; Campion & Latto, 1985; Davidoff & Warrington, 1993; Efron, 1968; Milner et al., 1991; Vecera & Behrmann, 1997). H.J.A.'s good performance on these tests, when contrasted with his difficulties in figure–ground perception, are consistent with a diagnosis of integrative agnosia; in this form of agnosia, the basic coding of shape is intact, but grouping and segmentation of more complex shapes (where segmentation cues are ambiguous) are impaired.

SECTION B

In Section B, we present data from an experimental analysis of object processing in S.A. and H.J.A. Three experiments are reported. Experiments 1 and 2 examined figure-ground segmentation in more detail, to assess whether, at a finer grained level, differences exist in the procedures that determine figure-ground perception in the patients. Experiment 1 used overlapping line drawings, but instead of requiring picture naming (Section A), we used either name verification (Experiment 1a) or visual tracing of an exemplar (Experiments 1b–1d). We examined how well the patients performed with drawings that were simply outline forms or drawings that included internal details (see Figure 4). Riddoch and Humphreys (1987a) reported that H.J.A. was particularly impaired at recognizing objects with internal detail, with internal details being used to segment objects inappropriately into separate parts. Here we test whether this oversegmentation could be observed directly, with a production task that shows the output of the segmentation process; we also test whether the same held for S.A. The contrast between name verification (Experiment 1a) and visual tracing (Experiment 1b–d) evaluates a further factor, which is the extent to which a patient may be able to use top-down knowledge to ameliorate a perceptual deficit in object processing. Note that top-down processing is more likely to play a role in the name verification task (Experiment 1a) than in visual tracing (Experiment 1b–d). The data presented in Section A indicated that S.A. had an “earlier” perceptual impairment than H.J.A. (e.g., in basic form coding itself), yet her identification of line drawings was somewhat better. One contributing factor might be that S.A. is better able to use her (spared) top-down knowledge to interpret degraded perceptual input. This was tested more directly in Experiments 1b–1d. However, while the data from Experiment 1c revealed that while S.A. was better able to use top-down information than H.J.A. in a name verification task (Experiment 1a), the information was insufficient to help her to segment target contours within a set of overlapping stimuli. In a further

experiment (Experiment 1d) we examined whether S.A. was able to segment a defining feature—rather than the whole contour—of the target item.

In Experiment 2 we employed a different approach to figure-ground segmentation by examining performance on contour-tracing tasks. In these experiments abstract stimuli were used, where stored knowledge could not influence performance. There were three separate subexperiments. In the first (Experiment 2a), two overlapping contours were presented (see Figure 5a, on p. 75). There were also two “beads” present, which could fall either on the same or on different contours. The task was to indicate whether the beads fell on the same or on different contours. Work with normal participants (Jolicouer, Ullman, & MacKay, 1986), plus single-cell recordings in the monkey (Roelfsema, Lamme, & Spekreijse, 2000), suggest that this task is achieved by a “curve tracing” operation, in which attention is scanned serially along the lines. Is this process spared in the patients? In the second subexperiment (Experiment 2b), the contours formed irregular “amoeba-like” shapes. Either the two beads both lay within the shape, or one lay inside and the other outside (see Figure 5b, on p. 75). Here we examined whether patients were able to use the global shape of the form to make figure-ground judgements (see Van Selst & Jolicouer, 1995, for prior evidence with normal participants). In the third experiment (Experiment 2c), two “amoeba-like” shapes overlapped (see Figure 5c, on p. 75). Either the beads lay on the contour of a single shape, or one bead lay on the contour of each shape. The task was to decide whether the beads lay on the same shape or on different shapes. In this last experiment there is additional stress on any figure-ground segmentation procedures since judgements require correct contour assignment globally across the shapes. We test whether performance can be maintained by the patients under these more taxing conditions. Experiment 3 assessed the ability of the patients to derive global and local form information using a compound letter task in which the patients had to identify letters at either the local or the global levels.

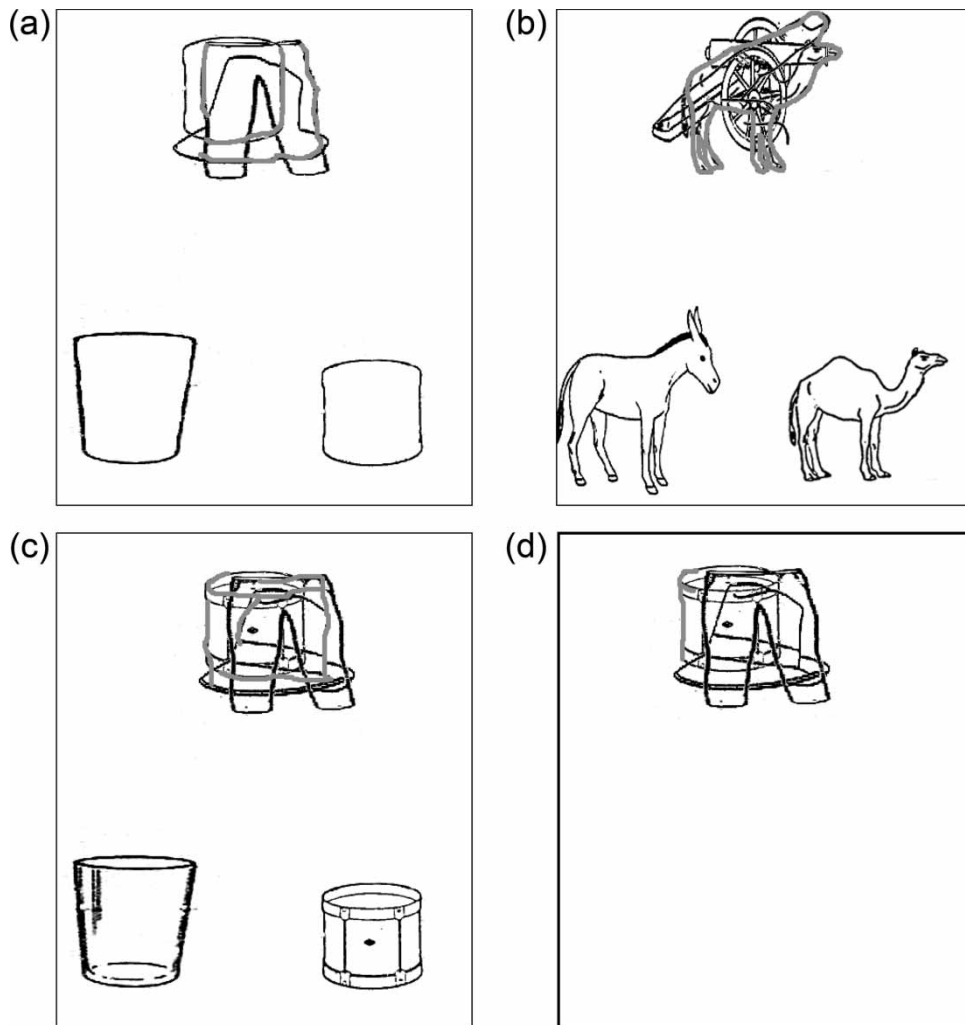


Figure 4. Examples of the stimuli used in Experiment 1. (a) An example of S.A.'s tracing round an outline within overlapping figures (target = drum; Experiment 1b). (b) An example of H.J.A.'s tracing round a detailed line drawing within overlapping figures (target = camel; Experiment 1b). (c) An example of S.A.'s tracing round the contour of a drum (detailed line drawing) within overlapping figures (Experiment 1b). (d) S.A.'s depiction of a "critical feature" of a target object (drum). When asked to specify the critical feature of a drum, either from a line drawing or from the object name, she stated "skin top" for the picture and "round, with a skin top for banging" given the name (Experiment 1c). (Figure can be seen in colour online.)

EXPERIMENT 1: SEGMENTING OVERLAPPING LINE DRAWINGS

Method

Stimuli

A total of 40 items were selected from the Snodgrass and Vanderwart (1980) set of line

drawings. There were equal numbers of animate and inanimate items. According to the ratings provided by Snodgrass and Vanderwart, the mean familiarity was 2.7 ($SD = 0.7$) and 3.7 ($SD = 0.8$), $t(38) = -4.3$, $p < .0001$, for the animate and inanimate items, respectively. The mean complexity was 3.7 ($SD = 0.7$) and 2.6 ($SD = 0.6$), $t(38) = 5.7$, $p < .0001$, for animate and inanimate

items, respectively. A measure of the similarity of the outlines of the shapes, the mean contour overlap, was 18.8 ($SD = 5.7$) and 13.8 ($SD = 5.9$), $t(38) = 2.5$, $p < .02$, for animate and inanimate items, respectively (Humphreys, Riddoch, & Quinlan, 1988), consistent with the animate objects belonging to categories with globally similar exemplars (Humphreys & Forde, 2001; data from Humphreys et al., 1988). Individual object stimuli were normalized for size and fitted into a 7×7 -cm virtual box. Three overlapping stimuli fitted into an 8×8 -cm virtual box.

In the name verification condition (Experiment 1a), either a single item or three overlapping items were presented. There were three overlapping items: the target and two other items drawn at random from the Snodgrass and Vandervart set (these items were never repeated). The stimuli were presented either as outlines or as detailed line drawings. There were 40 trials for each category of stimulus. The stimuli were randomized for presentation. All items were presented twice, once with the correct and once with the incorrect name (this was the name of the visually similar distractor from the match-to-sample study; $N = 80$ trials for both detailed and outline drawing conditions).

For the matching tasks (Experiments 1b and 1c), the same items as those in the name verification task above were used. In addition, two individual items (the target and another, different, distractor) were placed approximately 10 cm below the overlapping items, 5 cm apart. The distractor item was selected to be visually similar to the target when presented in outline. In general, the target and distractor came from the same category (living thing or artefact; e.g., cup and bowl; apple and strawberry), although a few distractors crossed category in cases where the line drawings corresponding to these items were visually similar (e.g., fork and celery; screw and caterpillar). As before, the stimuli were presented as both detailed line drawings and outlines. The task was to trace around the item within the overlapping set that was physically identical to one of the two items below. Only S.A. performed Experiments 1c and 1d. In both experiments, stimulus presentation

was identical to that in Experiment 1a. The name of one of the three overlapping items was presented auditorily, and S.A. was asked to trace around that item (Experiment 1c) or to trace around its identifying feature (Experiment 1d).

Procedure

The matching task was performed before the name verification task, and there was an interval of 3 months between Experiments 1a and 1b. Experiment 1c (matching to a written name) was performed 9 months after Experiment 1b. Experiment 1d, segmentation of an identifying feature of a target, took place 2 months after Experiment 1c.

Name verification (Experiment 1a). The single stimuli and overlapping stimuli were presented in two separate blocks. Within each block, the stimuli were randomized across items and across stimulus type (detailed line drawing vs. outline). Each patient was asked to study the stimuli and to write “yes” or “no” according to whether or not the written name corresponded to an item present.

Matching task (Experiment 1b). The stimuli were presented in a random order. Each patient was asked to compare the two single items at the bottom of the page with the three overlapping items above. Using a coloured pen, the patients were then asked to trace around the item in the overlapping set that was physically identical to one of the two stimuli shown below. There were no time constraints and no constraint on revisiting the items at the bottom of the page.

The data from Experiments 1a and 1b revealed a discrepancy between relatively good name verification and poor matching and contour tracing in S.A. This discrepancy was explored in two further conditions where only S.A. took part.

Tracing from a name (Experiment 1c). The procedure was identical to that described for Experiment 1a except that S.A. was asked to trace around the item corresponding to the name printed at the top of the stimulus array.

Feature detection task. The final experiment in this series was a feature detection task. The stimuli and procedure were identical to those described for Experiment 1a, except that now the instructions were to trace around an identifying feature of the target item. Data were collected for the detailed line drawings only. Subsequently, S.A. was presented with single detailed line drawing and was asked to name the identifying feature. In a further session, S.A. was given the name of the target items and was asked again what constituted that item's identifying features.

Data scoring

In the name verification task (Experiment 1a), responses were scored as either correct or incorrect. In the matching tasks (Experiments 1b and 1c), the data were scored in two ways. First we noted whether the target was traced correctly. Second, we noted whether the patients included contours from the distractors in their tracing. In Experiment 1d, the identity of the feature traced was noted. As in Experiments 1a and 1b we also noted whether distractor lines were included in addition to or as well as the target feature. We also coded the traced feature according to whether it fell within or protruded from the set of three overlapping pictures. The data from the sessions where S.A. was asked to identify the salient feature of the target items given either a picture of the item or its name were pooled to maximize the number of salient features associated with each target item.

Results

Examples of H.J.A.'s (detailed line drawings) and S.A.'s (outlines) performance for Experiment 1b are shown in Figure 4.

EXPERIMENT 1A: NAME VERIFICATION

The data are presented in Table 4.

The results were analysed separately for single and for overlapping drawings using binary logistic regression with the factors being patient (S.A. and H.J.A.), animacy (animate vs. inanimate), picture type (outline vs. detail), and match (correct name match vs. incorrect name match).

Single drawings

The significant effects from the SPSS output at Step 4 of the regression are displayed in Table 5. The main effect of animacy proved significant, indicating that overall performance was more accurate for inanimate items (133/160 and 123/160 for inanimate and animate items, respectively). The main effect of picture type was also reliable indicating better performance for detailed than for outline shapes (141/160 vs. 115/160 for detailed and outline shapes, respectively). The main effects of patient and match and all two-way and three-way interactions were unreliable (all $p > .05$). The four-way interaction (Patient \times Picture Type \times Animacy \times Match) was also insignificant ($p > .05$). The patients did not differ when required to verify single line drawings.

Overlapping drawings

With overlapping drawings there were significant main effects for patient and match and a reliable interaction between Picture Type \times Match. There was also a significant three-way interaction between Animacy \times Picture Type \times Match (see Table 6 for Step 11 of the logistic regression output). Further separate analyses were performed for animate and inanimate items to locate the locus of the interaction.

For animate items, there was a significant main effect of patient indicating that S.A. performed better than H.J.A. (68/80 vs. 48/80 correct); Wald (1) = 10.74, $p < .001$. The main effects of match and picture type were not reliable ($p > .05$). None of the two-way nor the three-way interaction was significant (all $p > .05$).

The results for inanimate items are shown in Table 7. There were significant main effects of patient (with S.A., 60/80 correct, performing better than H.J.A., 47/80 correct), picture type (there were more correct matches for detailed

Table 4. Number of trials where patients responded correctly in the name verification task as a function of whether single or overlapping objects were shown, with either outline contours only or as detailed line drawings

| Patient | Animate items | | | | Inanimate items | | | | Total |
|---------|---------------|--------|-------------|--------|-----------------|--------|-------------|--------|-------|
| | Single | | Overlapping | | Single | | Overlapping | | |
| | Outline | Detail | Outline | Detail | Outline | Detail | Outline | Detail | |
| S.A. | 33 | 38 | 33 | 35 | 30 | 39 | 26 | 37 | 271 |
| H.J.A. | 24 | 28 | 22 | 27 | 28 | 36 | 23 | 24 | 212 |

Note: $N = 40/\text{cell}$.

line drawings than for outline drawings, 58/80 vs. 49/80), and match (the rejection of the incorrect name was more accurate than acceptance of the correct name, 56/80 vs. 54/80). There were two significant two-way interactions: The Picture Type \times Match interaction showed that the patients were less likely to select the correct than the incorrect name for outline objects (19/40 vs. 30/40 for correct and incorrect name matches, respectively), while the reverse was true for detailed drawings (35/40 vs. 26/40 for correct vs. incorrect name matches, respectively). The Picture Type \times Patient interaction showed that H.J.A. performed at a similar level both for outline and for detailed line drawings (23/40 vs. 24/40 for outline and detailed drawings, respectively), while S.A. performed better with detailed line drawings (26/40 vs. 34/40 for outline and detailed drawings, respectively).

EXPERIMENT 1B: MATCHING AND TRACING TASK

Total completions

Overall, S.A. performed poorly. She completed 2/40 (one animate and one inanimate drawing) of the outline line drawings and 2/40 for the detailed line drawings (again, one animate and one inanimate drawing). H.J.A. performed relatively better. His data were analysed using binary logistic regression with the factors being animacy (living thing vs. artefact), picture type (outline vs. line drawing), and score (whether a target item was completed or not). The statistical output is presented in Table 8. There was a significant main effect of animacy with H.J.A. scoring better with inanimate than with animate items (13/40 vs. 28/40 for animate vs. inanimate items, respectively). There was also a main effect of condition

Table 5. Logistic regression output for name verification for single drawings for S.A. and H.J.A. in Experiment 1a

| Step 4 ^a | B | SE | Wald | df | Sig. | Exp(B) |
|---------------------|-------|-------|--------|----|------|--------|
| Animacy | -2.60 | 0.70 | 13.94 | 1 | .000 | 0.074 |
| Picture type | -1.35 | 0.63 | 4.59 | 1 | .032 | 0.259 |
| Constant | 2.197 | 0.527 | 17.380 | 1 | .000 | 9.000 |

Note: Hosmer and Lemeshow Goodness of Fit Test, $\chi^2(7) = 0.54$, $p > .05$. The final step of the SPSS output for binary logistic regression is reported. The Wald statistic uses the estimated regression coefficients (B) and their standard errors (SE) to compute a chi-square distribution. Exp(B) is an indicator of the change in odds resulting from a unit change in the predictor. The backward method of regression has been used. The Hosmer–Lemeshow goodness-of-fit statistic has been used to assess how well the chosen model fits the data. This method of reporting the output of the binary logistic regression is recommended by Field (2005).

^aVariable(s) entered on Step 1: Patient, Animacy, Picture type, Match, Animacy \times Patient, Picture Type \times Patient, Match \times Patient, Animacy \times Picture Type, Animacy \times Match, Picture Type \times Match, Animacy \times Picture Type \times Patient, Picture Type \times Match \times Patient, Animacy \times Picture Type \times Match, Animacy \times Picture Type \times Match \times Patient.

Table 6. Logistic regression output for name verification for overlapping drawings for S.A. and H.J.A. in Experiment 1a

| Step 1 ^a | B | SE | Wald | df | Sig. | Exp(B) |
|--------------------------------|---------|-------|--------|----|------|--------|
| Patient | 1.157 | 0.269 | 18.567 | 1 | .000 | 3.181 |
| Match | 0.930 | 0.356 | 6.813 | 1 | .009 | 2.535 |
| Picture Type × Match | - 1.860 | 0.456 | 16.668 | 1 | .000 | 0.156 |
| Animacy × Picture Type × Match | 1.291 | 0.502 | 6.615 | 1 | .010 | 3.638 |
| Constant | 0.243 | 0.205 | 1.404 | 1 | .236 | 1.275 |

Note: Hosmer and Lemeshow Goodness of Fit Test, $\chi^2(5) = 0.77, p > .05$. The final step of the SPSS output for binary logistic regression is reported. The Wald statistic uses the estimated regression coefficients (B) and their standard errors (SE) to compute a chi-square distribution. Exp(B) is an indicator of the change in odds resulting from a unit change in the predictor. The backward method of regression has been used. The Hosmer–Lemeshow goodness-of-fit statistic has been used to assess how well the chosen model fits the data. This method of reporting the output of the binary logistic regression is recommended by Field (2005).

^aVariable(s) entered on Step 1: Patient, Animacy, Picture type, Match, Animacy × Patient, Picture Type × Patient, Match × Patient, Animacy × Picture Type, Animacy × Match, Picture Type × Match, Animacy × Picture Type × Patient, Picture Type × Match × Patient, Animacy × Picture Type × Match, Animacy × Picture Type × Match × Patient.

with better performance for outlines (27/40 correct) than for detailed line drawings (14/40 correct).

The scores indicating whether contours from the distractors were included in the response are presented in Table 9 (the maximum score per cell, had distractor contours been included on every trial, was 20). These data were subjected to binary logistic regression with the factors being patient (S.A. and H.J.A.), animacy (animate vs. inanimate), and picture type (outline vs. detail). Distractor inclusion was the dependent variable (whether contours from the distractor were

included in the response or not). The output for Step 4 of the regression is shown in Table 10. There was one main effect of animacy and a significant two-way interaction of Animacy × Picture Type. The Animacy × Picture Type interaction showed that there was little difference between animate and inanimate items whether distractor lines were included in outline drawings (13/40 vs. 15/40 for animate vs. inanimate items, respectively), but with detailed drawings distractor lines were more likely to be included with animate targets (26/40 vs. 16/40 for animate vs. inanimate items, respectively).

Table 7. Logistic regression output for name verification for inanimate overlapping drawings for S.A. and H.J.A. in Experiment 1a

| Step 3 ^a | B | SE | Wald | df | Sig. | Exp(B) |
|------------------------|---------|-------|--------|----|------|--------|
| Patient | 2.289 | 0.714 | 10.270 | 1 | .001 | 9.869 |
| Picture type | 1.249 | 0.610 | 4.189 | 1 | .041 | 3.486 |
| Match | 1.569 | 0.638 | 6.052 | 1 | .014 | 4.804 |
| Picture Type × Patient | - 1.945 | 0.861 | 5.101 | 1 | .024 | 0.143 |
| Picture Type × Match | - 2.776 | 0.802 | 11.995 | 1 | .001 | 0.062 |
| Constant | - 0.315 | 0.436 | 0.522 | 1 | .470 | 0.730 |

Note: Hosmer and Lemeshow Goodness of Fit Test, $\chi^2(6) = 1.3, p > .05$. The final step of the SPSS output for binary logistic regression is reported. The Wald statistic uses the estimated regression coefficients (B) and their standard errors (SE) to compute a chi-square distribution. Exp(B) is an indicator of the change in odds resulting from a unit change in the predictor. The backward method of regression has been used. The Hosmer–Lemeshow goodness-of-fit statistic has been used to assess how well the chosen model fits the data. This method of reporting the output of the binary logistic regression is recommended by Field (2005).

^aVariable(s) entered on Step 1: Patient, Picture type, Match, Picture Type × Patient, Match × Patient, Picture Type × Match, Picture Type × Match × Patient.

Table 8. Logistic regression output for total completions by H.J.A. in Experiment 1b

| Step 2 ^a | B | SE | Wald | df | Sig. | Exp(B) |
|---------------------|--------|-------|--------|----|------|--------|
| Animacy | -1.836 | 0.545 | 11.365 | 1 | .001 | 0.159 |
| Picture type | 1.636 | 0.545 | 9.021 | 1 | .003 | 5.134 |
| Constant | 0.167 | 0.409 | 0.166 | 1 | .684 | 1.181 |

Note: Hosmer and Lemeshow Goodness of Fit Test, $\chi^2(2) = 0.82$, $p > .05$. The final step of the SPSS output for binary logistic regression is reported. The Wald statistic uses the estimated regression coefficients (B) and their standard errors (SE) to compute a chi-square distribution. Exp(B) is an indicator of the change in odds resulting from a unit change in the predictor. The backward method of regression has been used. The Hosmer-Lemeshow goodness-of-fit statistic has been used to assess how well the chosen model fits the data. This method of reporting the output of the binary logistic regression is recommended by Field (2005).

^aVariable(s) entered on Step 1: Animacy, Picture type, Animacy \times Picture Type.

EXPERIMENT 1C: TRACING FROM A NAME

The data from Experiments 1a and 1b reveal a contrast that is particularly striking for S.A. She was better than H.J.A. at verifying whether a named stimulus was present in a set of overlapping figures (Experiment 1a), while she was strikingly poor at tracing a target in the overlapping set when given a visual exemplar (Experiment 1b). In Experiment 1c, S.A. had to trace a target in the overlapping set when she was given the object's name. She remained very poor at this, completing correctly only 7/40 outline drawings and 1/40 detailed line drawings (Fisher's Exact Test, $p > .05$). As in Experiment 1b, she had a tendency to include distractor lines in her response (see Figure 4c). The numbers of trials where a distractor contour was included are presented in Table 9. These data were subjected to a binary logistic regression with the factors being experiment (1b and 1c), animacy (animate vs.

inanimate), and picture type (outline vs. detail). Distractor inclusion (inclusion vs. no inclusion) was again the dependent variable. The output from Step 6 of the regression is presented in Table 11. The main effect of animacy was reliable and indicated that S.A. was more likely to include distractor lines from animate items (46/80) than from inanimate items (32/80). The main effect of experiment and the interaction between experiment and animacy approached significance. S.A. tended to include more distractor lines in Experiment 1c than in Experiment 1b (37/80 vs. 41/80 for Experiments 1b and 1c, respectively), and the effect was particularly apparent for animate items (27/80 vs. 19/80 for inclusion of distractor lines with animate targets, and 18/80 vs. 14/80 for inclusion of distractor lines with inanimate targets in Experiments 1c and 1b, respectively).

EXPERIMENT 1D: DETECTING DISTINCTIVE FEATURES

Given that S.A. remained poor at tracing, even when presented with the name of the target object (Experiment 1c), the question remains as to how she could verify a target amongst overlapping distractors. Experiment 1d assessed whether S.A.'s good verification performance (Experiment 1a) arose because she could detect critical features of stimuli even when they were overlapping. Here she was asked to trace the critical features of a named target (e.g., Figure 4d shows her

Table 9. Number of trials where patients included lines from the distractors in their responses in Experiments 1b and 1c

| | Animate items | | Inanimate items | |
|----------------|---------------|--------|-----------------|--------|
| | Outline | Detail | Outline | Detail |
| S.A. (Exp. 1b) | 8 | 11 | 10 | 8 |
| S.A. (Exp. 1c) | 14 | 13 | 8 | 6 |
| H.J.A. | 5 | 15 | 5 | 8 |

Note: $N = 20$ /cell.

Table 10. Logistic regression output for inclusion of distractor lines in Experiment 1b

| Step 6* | B | SE | Wald | df | Sig. | Exp(B) |
|------------------------|---------|-------|-------|----|------|--------|
| Animacy | 1.077 | 0.403 | 7.134 | 1 | .008 | 2.935 |
| Animacy × Picture Type | − 1.350 | 0.473 | 8.141 | 1 | .004 | 0.259 |
| Constant | − 0.458 | 0.229 | 3.980 | 1 | .046 | 0.633 |

Note: Hosmer and Lemeshow Goodness of Fit Test, $\chi^2(1) = 0.0$, $p > .05$. The final step of the SPSS output for binary logistic regression is reported. The Wald statistic uses the estimated regression coefficients (B) and their standard errors (SE) to compute a chi-square distribution. Exp(B) is an indicator of the change in odds resulting from a unit change in the predictor. The backward method of regression has been used. The Hosmer–Lemeshow goodness-of-fit statistic has been used to assess how well the chosen model fits the data. This method of reporting the output of the binary logistic regression is recommended by Field (2005).

*Variable(s) entered on Step 1: Patient, Animacy, Picture type, Animacy × Patient, Picture Type × Patient, Animacy × Picture Type, Animacy × Picture Type × Patient.

performance in response to the target name “drum”). Performance with overlapping stimuli was compared with her performance with single stimuli and when she was asked to describe verbally the critical features for identification, when given the object’s name. Did S.A. use the same features with overlapping and nonoverlapping items?

First, we compared S.A.’s success at tracing a part of the target object, without including contours from distractors, when she was asked just to trace a critical feature compared with when she had to trace the whole stimulus (Experiment 1b). S.A. was more accurate in tracing a feature than in tracing the entire contour of the target object (34/40 vs. 2/40 correct for the feature vs. the entire contour correct, respectively; Fisher’s Exact Test, $p < .0001$). Three errors represented a failure to include any contours of the target

object (axe, salt cellar, toaster); for a further three items she selected a component of the correct contour whilst also including contours from distractor items (thimble, beetle, and pepper).

S.A. listed 47 critical features when viewing a single picture while she listed 50 features when given the object’s name. There were a total of 57 different features listed. S.A. traced only 14/57 (24.6%) of these features when tracing with overlapping forms (including all the features listed from single objects and from names. S.A. was much less likely to indicate the same critical feature for overlapping stimuli than for single objects; $\chi^2(1) = 38.4$, $p < .0001$. When asked to depict the critical feature in a display, S.A. was more likely to trace the unoccluded contour of the target item than an occluded contour. Of the 34 items where she correctly traced a feature from the correct object in an overlapping set,

Table 11. Logistic regression output for inclusion of distractor lines for S.A. in Experiments 1b and 1c

| Step 6 ^a | B | SE | Wald | df | Sig. | Exp(B) |
|-------------------------------------|---------|-------|-------|----|------|--------|
| Animacy | 0.952 | 0.352 | 7.318 | 1 | .007 | 2.591 |
| Animacy × Picture Type × Experiment | − 0.952 | 0.529 | 3.236 | 1 | .072 | 2.386 |
| Constant | − 0.405 | 0.228 | 3.157 | 1 | .076 | 2.667 |

Note: Hosmer and Lemeshow Goodness of Fit Test, $\chi^2(3) = 0.001$, $p > .05$ (Step 5). The final step of the SPSS output for binary logistic regression is reported. The Wald statistic uses the estimated regression coefficients (B) and their standard errors (SE) to compute a chi-square distribution. Exp(B) is an indicator of the change in odds resulting from a unit change in the predictor. The backward method of regression has been used. The Hosmer–Lemeshow goodness-of-fit statistic has been used to assess how well the chosen model fits the data. This method of reporting the output of the binary logistic regression is recommended by Field (2005).

^aVariable(s) entered on Step 1: Experiment, Animacy, Picture type, Animacy × Experiment, Picture Type × Experiment, Animacy × Picture Type, Animacy × Picture Type × Experiment.

there were only 6 (17.6%) where she included a feature that overlapped with the other stimuli in the display, and for 28 items she traced a nonoverlapping feature. For 16/28 (57.1%) of the items, this depicted feature was not part of the composite list generated for single stimuli and for names.

Discussion

There are several interesting points to note. Perhaps most striking is the contrast between the patients on the matching and name verification tasks (Experiments 1a and 1b). Using the same overlapping stimuli, H.J.A. was much better than S.A. when the task required tracing around a target shape based on at least some form of match with the sample stimuli shown below the overlapping forms. S.A. was at floor on this version of the task. However, when the task was name verification, S.A. performed better than H.J.A. These data confirm the presence of a perceptual impairment in both patients since both were far from ceiling with the overlapping stimuli. However, there is also a considerable contrast in the abilities of the two patients to use top-down knowledge to match to their impaired perceptual representations: S.A. is much better than H.J.A. at doing this, despite appearing to have a worse perceptual deficit in segmenting the figures in the first place. A deficit between apparently poor perceptual encoding and relatively good object recognition has been noted before in some patients, consistent with patients sometimes remaining able to use top-down knowledge to mask a deficit (Charnallet, Rousset, Carbonnel, & Pellat, 1996). However, to the best of our knowledge this is the first demonstration of a direct contrast between two patients using the same stimuli. Experiments 1c and 1d also provide information about how S.A. was able to use her top-down knowledge to facilitate object verification. Experiment 1c showed that S.A. remained poor at tracing objects even when given their name, suggesting that top-down knowledge did not help her overcome her basic deficit in segmenting overlapping shapes. In Experiment 1d, S.A. depicted nonoverlapping

parts of overlapping shapes, when asked to indicate a distinctive feature of an object and the distinctive feature she listed in this case very often differed from the distinctive feature she depicted in a nonoverlapping shape or when verbally describing the critical aspects of an object. These last results indicate that S.A. continued to have difficulty in segmenting overlapping stimuli, but she was able to apply top-down knowledge in a highly flexible manner, allowing her to verify an object from nonoverlapping features that were not (in other circumstances) judged critical.

Second, H.J.A. was worse in segmenting detailed line drawings than outline forms (at least in Experiment 1b), which fits with previous work showing that H.J.A. is impaired at processing objects with local internal detail (Lawson & Humphreys, 1999; Riddoch & Humphreys, 1987a). Here we extend previous results on object recognition to a task where only a form of copying was required. This provides direct evidence for a perceptual locus to the effects of internal detail observed with H.J.A.

Third, in the match-to-sample task of Experiment 1b, H.J.A. performed better with inanimate than with animate items. This fits with H.J.A.'s naming data (Section A) and indicates a problem in the perceptual processing of animate items. S.A.'s performance at this same task was close to floor, and it was not therefore possible to test for an effect of object category. Nevertheless, it is interesting to note that, when tracing from a name, S.A. tended to include more distractor lines when reproducing animate than inanimate objects. This may reflect the greater complexity of animate items, but it does not match with her better identification of animate items.

EXPERIMENT 2: CURVE TRACING

Experiment 2 examined curve tracing with simple lines (Experiment 2a), a single "amoeba" (Experiment 2b), and overlapping "amoebae" (Experiment 2c).

EXPERIMENT 2A: SIMPLE LINES

Method

On each trial two pieces of “string” were represented in a 2D drawing (see Figure 5a). There were also two “beads”, which could be positioned either on the same or on different strings. In both instances the distance between the beads was manipulated (1, 2, and 3 cm). There were 120 trials in total (60 same and 60 different). For both same and different trials there were equal numbers of trials with the beads 1, 2, and 3 cm apart. S.A. and H.J.A.’s performance was compared with that of 10 control participants (mean age 66.2 years, $SD = 6.8$). Stimuli were presented individually on cards; participants were allowed unlimited viewing time.

Results

Accuracy data

The accuracy data are presented in Table 12.

S.A. found the task very difficult, and performance was close to chance (she scored 56.7% correct for “same” and 68.3% correct for “different”). Accuracy on same and different trials did not differ significantly, $\chi^2(1) = 1.7, p > .05$, and was therefore collapsed to determine whether varying the spacing of the beads affected performance. S.A. scored 67.5%, 55.0%, and 60% correct for 1, 2, or 3 cm apart, respectively. There was no significant difference in these scores, $\chi^2(2) = 1.3, p > .05$.

Overall, H.J.A. performed better than S.A. (94/120 vs. 73/120), $\chi^2(1) = 8.6, p < .003$. Performance on same and different trials did not differ significantly, $\chi^2(1) = 0.79, p > .05$, and was collapsed to determine the effect of spacing the beads. H.J.A. scored 82.5%, 77.5%, and 75% correct for 1, 2, or 3 cm apart, respectively. There was no significant difference in these scores, $\chi^2(2) < 1.0, p > .05$.

The controls scored 86.5, 88.3, and 86.0% for bead spacing 1, 2, and 3 cm apart, respectively, $F(2, 18) = 0.75, p > .05$.

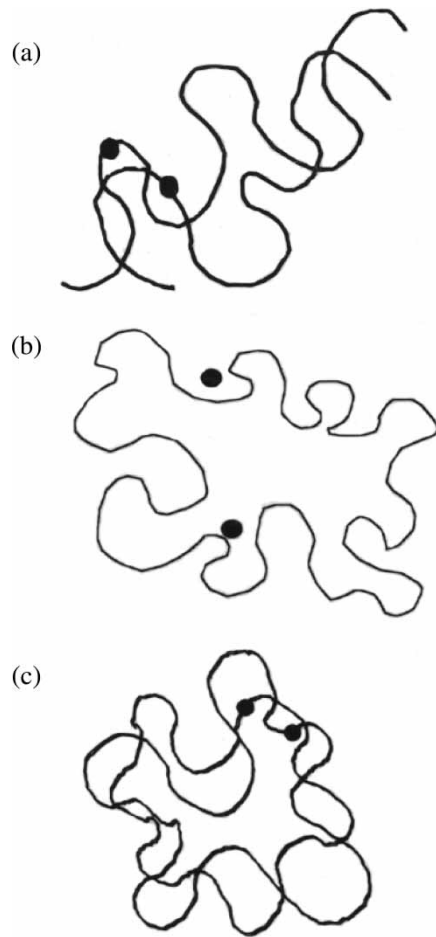


Figure 5. Stimuli used in Experiment 2. (a) Overlapping “strings” (are the dots on the same or different strings?). (b) Single shapes (are the dots both inside, both outside, or one in and one out?). (c) Overlapping amoebae (are the dots on the same or different shapes?).

Table 12. Number of correct reports on the contour-tracing task in Experiment 2a

| | Distance between beads | | |
|-------------------------------|------------------------|------------|------------|
| | 1 cm | 2 cm | 3 cm |
| S.A. | 27 | 22 | 24 |
| H.J.A. | 33 | 31 | 30 |
| Control mean (<i>SD</i>) | 34.5 (3.4) | 35.3 (2.7) | 34.4 (2.7) |

Note: $N = 40$.

Response time data

Since S.A.'s accuracy was close to chance, her response times (RTs) could not be analysed. For the remaining participants, the RT data were trimmed. Any data point more than 2 standard deviations from the mean of that condition was removed and was treated as an error. The data for H.J.A. and the controls are shown in Table 13.

H.J.A.'s data were analysed by treating each RT as a separate subject, which was entered into a single-factor analysis of variance (ANOVA; see Young, Hallowell, & Hay, 1987). There was a significant main effect of distance, $F(2, 93) = 4.18, p < .02$, with a significant linear component: linear regression, $F(1, 8) = 8.12, p < .005$. Post hoc tests revealed that performance when the dots were 1 cm apart was quicker than when they were 3 cm apart ($p < .02$); no other comparisons proved significant (all $p < .05$).

There was also a significant effect of distance for the controls, $F(1, 9) = 23.2, p < .001$, and again the linear component was reliable, $F(1, 9) = 23.1, p < .001$. The rate of increase in RTs, as the distance between the dots increased, was comparable for H.J.A. and the controls, when scaled by the overall mean RT to respond (H.J.A., 230 ms/cm; control mean, 280 ms/cm).

EXPERIMENT 2B: INSIDE-OUTSIDE RELATIONS IN AN "AMOEBEA"

Method

Enclosed "amoeba" shapes with irregular boundaries were created. The shapes were categorized as large or small (5.5×5.5 cm and 2×2 cm, respectively). There were 30 large and 30 small shapes. Each shape was presented with two black dots, which could both fall within the shape or

both outside the shape, or one could fall inside the shape while the other fell outside. For each shape size there were 10 trials for each of the different dot conditions. The task was to identify the locations of the dots as quickly as possible. Responses were timed with a stop watch, and numbers of errors were recorded. Stimuli were presented on cards; viewing time was unlimited. Examples of the stimuli are shown in Figure 5b.

Results

The data for large and small displays were very similar, and so the results were pooled. The results are presented in Tables 14 and 15.

Table 14. Number of correct reports on the inside-outside task with amoebae in Experiment 2b

| | Same | Different |
|-------------------|----------------|----------------|
| S.A. | 32/40 | 17/20 |
| H.J.A. | 37/40 | 18/20 |
| Control mean (SD) | 37.6/40 (1.78) | 18.8/20 (0.42) |

Note: "Same" refers to when both dots fell on the same shape, "Different" to when each dot fell on the outline of a different shape.

Table 15. Mean correct response times on the inside-outside task with amoebae in Experiment 2b

| | Position of black dots | |
|-------------------|------------------------|-----------------|
| | Both in or out | One in, one out |
| S.A. | 6.5 (2.3) | 9.4 (3.8) |
| H.J.A. | 2.92 (0.77) | 3.67 (1.45) |
| Control mean (SD) | 1.11 (0.20) | 1.27 (0.19) |

Note: Response times in s.

Table 13. Mean correct response times for H.J.A. on the contour-tracing task in Experiment 2a

| | Distance between beads | | |
|-------------------|------------------------|------------|------------|
| | 1 cm | 2 cm | 3 cm |
| H.J.A. | 6.97 | 8.19 | 8.81 |
| Control mean (SD) | 2.02 (0.7) | 2.54 (0.7) | 2.72 (0.8) |

Note: Response times in s.

The RT data were trimmed as in Experiment 2a. S.A. found the task difficult. She had very slow RTs (overall average RT for S.A. = 8.5 s, $SD = 4.9$), and her error rate for “same” responses fell more than 2 standard deviations outside the control mean. H.J.A. made few errors, and these fell within the control range. H.J.A.’s RTs were slower than the controls but it is difficult to assess whether this is a general RT slowing rather than an indicator of perceptual difficulty.

EXPERIMENT 2C: OVERLAPPING AMOEBAE

Method

Similar shapes to those used in Experiment 2b were used but in this case the shapes were overlapping (for examples of the stimuli, see Figure 5c). The displays consisted of either two small or two large shapes (60 trials each). Two dots were also presented on each trial, and these either fell on the outline of a single shape or fell on the outlines of different shapes. The dots were 1, 2, or 3 cm apart (40 trials each). The task was to indicate

Table 16. Number of correct reports on the task with the overlapping amoebae in Experiment 2c

| | Distance between dots | | |
|----------------------------|-----------------------|------------|------------|
| | 1 cm | 2 cm | 3 cm |
| H.J.A. | 34 | 33 | 26 |
| Control mean (<i>SD</i>) | 36.6 (1.5) | 33.8 (1.6) | 34.2 (3.5) |

Note: $N = 40$.

Table 17. Mean correct response times on the task with overlapping amoebae in Experiment 2c

| | Distance between dots | | |
|----------------------------|-----------------------|-----------|-----------|
| | 1 cm | 2 cm | 3 cm |
| H.J.A. | 10.9 | 11.5 | 13.4 |
| Control mean (<i>SD</i>) | 2.3 (0.2) | 2.8 (0.3) | 3.1 (0.3) |

Note: Response times in s.

whether the dots fell on the same or on different shapes. Reaction times were measured with a stop-watch, and errors were recorded.

Results

S.A. was unable to perform the experiment, which was abandoned after 60 trials. She indicated that she was simply guessing, and the data showed she was at chance (23/60, 38.3% correct). The results for the control participants and H.J.A. are presented in Tables 16 and 17.

H.J.A.’s errors were similar to the controls when the dots were 1 cm and 2 cm apart, but they fell 2 standard deviations outside the control mean when the dots were 3 cm apart. H.J.A.’s RTs were analysed by treating each RT as a separate subject in a single-factor ANOVA (see Young et al., 1987). There was a significant main effect of distance, $F(2, 90) = 3.4$, $p < .04$, and a reliable linear component: linear regression, $F(1, 91) = 6.1$, $p < .02$. The controls also showed a linear effect of distance on RTs, $F(1, 9) = 13.2$, $p < .005$. As with Experiment 2a, the RT increase as the distance between the dots increased was similar for H.J.A. and the controls when scaled by the mean RT (H.J.A.: 210 ms/cm; mean controls 290 ms/cm). It is noteworthy that the rates here are close to those in Experiment 2a.

Discussion

The data demonstrate that S.A. was extremely impaired at curve tracing, with simple (Experiment 2a) as well as complex stimuli (Experiment 2c), and she was also poor at judging inside–outside relations in complex, unfamiliar shapes (Experiment 2b). Thus her problems with tracing contours in Experiment 1 were not due to impairment in eye–hand coordination, given that no motor responses were required here. In contrast, although his overall RTs were longer than those of the controls, H.J.A. performed relatively normally on these tasks, with his accuracy falling below control levels only under the more difficult condition (with widely spaced dots on overlapping amoebae, in

Experiment 2c). In addition, H.J.A. presented evidence of serially shifting his attention at a normal rate to carry out the curve-tracing tasks, since the effects of distance on his RTs were similar to those found with control participants (when the effects of distance were scaled by absolute RTs). This fits with prior data showing intact serial scanning of attention in search tasks in H.J.A. (Humphreys et al., 1992).

S.A.'s deficit on these tasks may be attributed to various impairments. One could be a problem in scanning spatial attention, which prevents her (internally) tracing along the contours. However, we doubt this is the case. In a standard serial search task, requiring the detection of a colour-form conjunction target (green triangle vs. red triangle and green circles; Treisman & Gelade, 1980), S.A. showed a search rate comparable to that of age-matched controls (when scaled by absolute RTs her search rate increased by a ratio of 0.03 per item, whilst controls increased by a ratio of 0.04 per item; search accuracy was normal). Note that this pattern of performance also distinguishes S.A. from cases of "dorsal simultanagnosia", who are typically very impaired at conjunction search tasks (Friedman-Hill, Robertson, & Treisman, 1995; Humphreys, Cinel, Wolfe, Olson, & Klempe, 2000). In this "purer" test of attention scanning, S.A. was normal. A second, more likely, possibility is that S.A. is impaired on these tasks because she is poor at encoding more global aspects of shape, so that for her any curve-tracing operation is not guided by global constraints (e.g., that where two lines cross, there is better continuation along the "same" curve than along the "different" curve—a judgement that requires relative weighting outside the local spatial region of the two possible continuations of the lines). If curve tracing is based only on local coding of the lines, then it will break down when the lines cross (Experiments 2a and 2c), or when more global shape information should be held to distinguish whether dots are inside or outside the overall contour (Experiment 2b). This proposal that S.A. operates locally when processing form information was tested more directly in Experiment 3, where the patients (and controls) were required to respond to hierarchical forms. In contrast to

S.A., H.J.A.'s relatively normal performance on the curve-tracing tasks suggests that he is able to compute information across wider spatial regions.

EXPERIMENT 3: RESPONDING TO HIERARCHICAL FORMS

In Experiment 3 we presented the patients with hierarchical compound letters and required them to respond to either the local or the global forms. In many cases participants respond with a bias towards responding to global forms, showing faster overall RTs to global stimuli and interference when global forms are incongruent with the responses required to local forms (Navon, 1977). However, this "global precedence" effect does depend on a number of factors including the size of the stimuli (Kinchla & Wolfe, 1976) and the density of the letters (Martin, 1979). Here we used stimuli with a size and density that induced a mild global precedence effect in normal participants (see Mevorach, Humphreys, & Shalev, 2005b). We assessed whether this effect would be increased or reduced in S.A. and H.J.A.

A number of recent imaging studies have shown distinctions between local and global processing in early prestriate cortex (e.g., using positron emission tomography, PET, Fink et al., 1997, and functional magnetic resonance imaging, fMRI, Sasaki et al., 2001). Sasaki et al. (2001) demonstrate that attention to local targets activates medial areas of the occipital cortex, while attention to global targets activates more lateral areas (see also Boeschoten, Kemner, Kenemans, & van England, 2005; Lux et al., 2004). A previous study with H.J.A. demonstrated an increased global precedence effect, which is consistent with the argument that medial occipital cortex subserves attention to local parts of shape (Humphreys, Riddoch, & Quinlan, 1985).

Method

Participants

S.A. and H.J.A.'s performance was compared with that of 10 control participants (mean age 66.2 years, $SD = 6.8$).

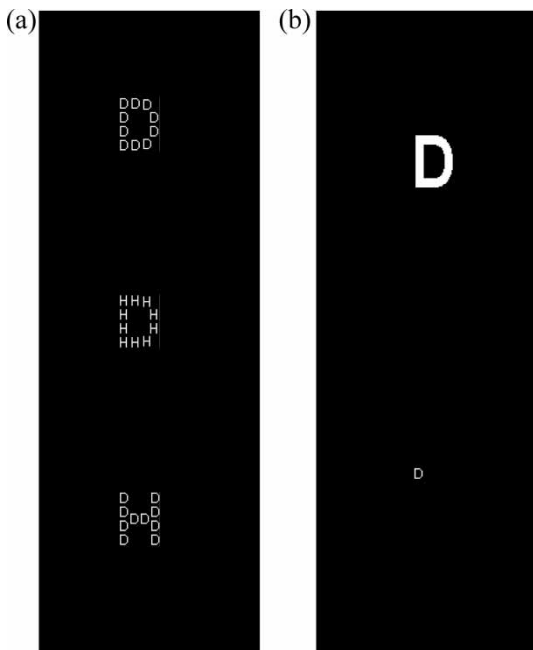


Figure 6. (a) Hierarchical stimuli used in Experiment 3. (b) Examples of the single letters.

Stimuli

Examples of the stimuli are shown in Figure 6. The global letter subtended $1.27^\circ \times 1.66^\circ$ of visual angle (in width and height, respectively), and each local letter subtended $0.26^\circ \times 0.38^\circ$. The interelement distance was 0.1° (see Mevorach et al., 2005b). Target letters (D or H) were present at a global and/or a local level. In the global condition, the target letter could be the same as the local letter (global D, local D; congruent condition), or the local letter could be associated with the opposite response (e.g., global D, local H; incongruent condition), or the local letter was not associated either response (e.g., global D, local I; neutral condition). In the local condition, the global letter could be congruent with the local (local D, global D), incongruent (local D, global H), or neutral (local D, global I) letter. All the stimuli were presented centrally and consisted of white letters against a black

background. There were two further conditions: one where a single block letter was presented the size of the local shape and one where it was the size of the global shape (see Figure 6b).

Procedure

The stimuli were presented on a PC using E-Prime software. Participants responded via the keyboard. The keys assigned to the target letters were counterbalanced across the experimental conditions. For each participant, there were four experimental conditions: two with hierarchical forms (respond local or global), and two with single letters. The order of the different conditions was randomized over participants. There were 120 trials for each task with the hierarchical forms (40 each where global and local letters were congruent, incongruent, and neutral), and 40 trials where the block letters were presented in isolation (20 for each of the target letters).³ Prior to each experimental condition, instructions were given as to which key should be used to respond to D and which to H; participants were instructed to respond as quickly and accurately as possible.

Results

For all the participants the data were trimmed as in Experiment 2.

Control participants

The RT data were initially entered into a two-factor repeated measure ANOVA. The factors were level (report of the letter at either the local or the global level) and congruency (the target letter was congruent, incongruent, or neutral with respect to the other letter in the display). Both main effects were significant: for level, $F(1, 9) = 5.3, p < .046$; for congruency, $F(2, 18) = 33.6, p < .0001$. However, while the lower bound epsilon for level was 1, it was .5 for congruency, suggesting a violation of sphericity; the data were therefore entered into a two-factor repeated measure multivariate analysis of variance

³H.J.A. performed the nonhierarchical conditions twice, a total of 80 trials each.

(MANOVA). There remained a significant main effect of congruency, $F(2, 9) = 15.66$, $p < .002$; Wilks's lambda = 0.203, $F(2, 18) = 15.7$, $p < .002$. Pairwise comparisons revealed that the congruent (mean 614 ms) and neutral (mean 631 ms) conditions were significantly different from the incongruent condition (mean 701 ms; $p < .001$ and $p < .01$ for congruent and neutral conditions, respectively), but that the congruent condition did not differ from the neutral condition ($p > .05$). For the MANOVA neither the main effect of level nor the interaction between level and congruency were reliable (both $p > .05$), although the trends were for RTs to be faster to global than to local figures and for interference effects (on incongruent trials) to be stronger on local responses. The means for each condition are shown in Figure 7a.

The RTs for the single letters were entered into a paired t test. The mean RT to the small letter was 586 ms, and to the large letter it was 495 ms; this difference was significant, $t(9) = 2.9$, $p < .02$. Control participants were faster to respond to the larger than to the smaller letter.

Errors followed the RT data and showed no evidence of a speed-accuracy trade-off. Errors were thus not analysed further (see Table 18).

Patient data

S.A. The analysis revealed a significant main effect of level, $F(1, 217) = 17.95$, $p < .0001$, indicating faster responses to local (655 ms) than to global stimuli (769 ms). Neither the main effect of congruency nor the interaction between level and congruency reached significance (both $p > .05$). The means for each condition are shown in Figure 7b. For the single block stimuli, *S.A.* responded more quickly to the small than to the large letter (556 vs. 612 ms), $t(75) = 29.5$, $p < .0001$. There were no signs of a speed-accuracy trade-off (see Table 18).

H.J.A. The RT data for *H.J.A.* showed a significant main effect of level, $F(1, 211) = 102.5$, $p < .0001$, and congruency, $F(2, 211) = 8.04$, $p < .0001$. *H.J.A.* responded faster to global than to local forms (928 ms vs. 1,658 ms for global and

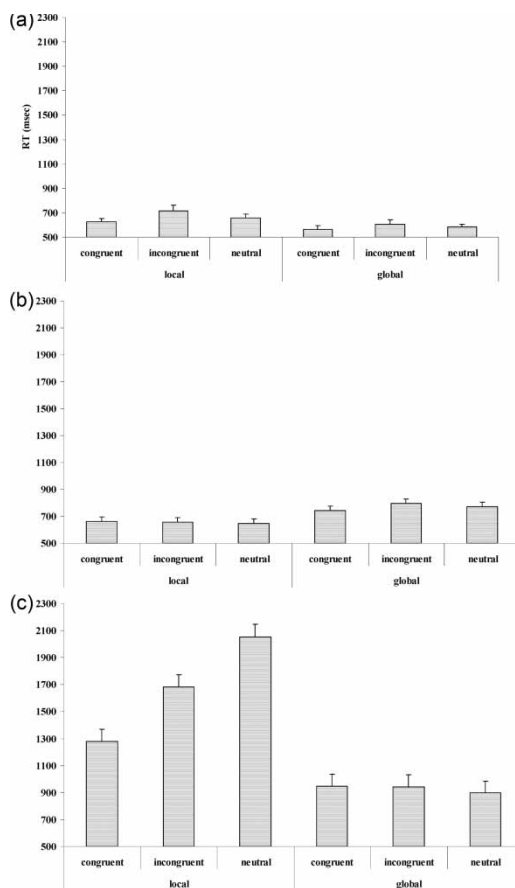


Figure 7. Response times for responses to the global or local letter in the congruent, incongruent, and neutral conditions in Experiment 3. (a) Data from controls. (b) Data from *S.A.* (c) Data from *H.J.A.*

local, respectively) and faster to congruent than to incongruent and neutral stimuli (a post hoc Tukey test showed that responses to congruent stimuli were significantly faster than those to neutral stimuli ($p < .001$), but that there was no difference between congruent and incongruent, and incongruent and neutral (both $p > .05$). The two-way interaction was significant, $F(2, 211) = 10.2$, $p < .0001$, indicating that the congruency effect was greater for local than for global arrays. See Figure 7c for the means in each condition.

With the single stimuli, *H.J.A.*'s average RT to large stimuli were faster than those to small stimuli (644 ms. vs. 1,142 ms), $t(149) = 23.8$, $p < .0001$.

Table 18. Percentages of error for responses to hierarchical stimuli in Experiment 3

| | <i>Local</i> | | | <i>Global</i> | | |
|----------|------------------|--------------------|----------------|------------------|--------------------|----------------|
| | <i>Congruent</i> | <i>Incongruent</i> | <i>Neutral</i> | <i>Congruent</i> | <i>Incongruent</i> | <i>Neutral</i> |
| Controls | 5.8 | 15.0 | 8.3 | 7.5 | 8.8 | 8.0 |
| S.A. | 7.5 | 2.5 | 7.5 | 2.5 | 17.5 | 5.0 |
| H.J.A. | 7.5 | 7.5 | 17.5 | 10.0 | 7.5 | 7.5 |

Note: $N = 40$.

There were again no signs of a speed–accuracy trade-off (Table 18).

Discussion

The results were very clear. Under conditions in which control participants showed a mild global precedence effect (Figure 7a), S.A. demonstrated a reverse, local precedence effect (Figure 7b), and H.J.A. an exaggerated global precedence effect (Figure 7c). For H.J.A. the magnitude of the global advantage (730 ms) was 78% of his RT to global stimuli, whereas the global advantage for the controls (100 ms) was just 19% of the RT to global forms. These effects were mirrored to some degree in the responses by the participants to single stimuli matched to the size of the local and global letters, except that, for the patients, the magnitudes of the differences in RTs to large and small stimuli were increased when the stimuli were presented in hierarchical displays. For S.A., there was a 56-ms advantage for small over large single letters, which was doubled when responses were made to hierarchical forms (an advantage of 115 ms for local over global stimuli, averaging across the congruent, incongruent, and neutral conditions). For H.J.A. there was an advantage of 498 ms for single large over small letters, relative to an overall advantage of 730 ms for global over local forms. In contrast, the differences shown in control participants in responding to the single large and small letters (91 ms) was close to the contrast between responding to local and global hierarchical forms (100 ms). Thus, over and above any effects of size per se, the patients showed effects of attending to the

elements in the context of hierarchical forms. This mirrors previous data reported with H.J.A. (Humphreys et al., 1985).

The results for S.A. indicate that she has an abnormally strong bias to attend to local elements (reversing the pattern present in controls). This fits with the idea that the dorsal occipital cortex is important for mediating attention to global aspects of shape. In contrast, H.J.A., with a more ventral and medial occipital lesion, has an abnormally strong bias to attend to global shape; for example, the size of the overall global advantage for H.J.A. was around four times as large as that observed with the controls, even when differences between global and local responses were scaled by absolute RTs to local forms. This is consistent with ventral medial occipital regions being necessary for attention to local form and with H.J.A. having abnormal difficulty in this process. The two patients show a dramatic difference in their processing of hierarchical forms.

The contrast between the processing of local and global aspects of hierarchical forms could reflect differential biases in responding to high- and low-spatial-frequency information. Global aspects of form can be conveyed through low-spatial-frequency components and more local aspects through high-spatial-frequency components (Badcock, Whitworth, Badcock, & Lovegrove, 1990). We have noted, also, that the patients show decreased contrast sensitivity functions. H.J.A.'s poor sensitivity for high spatial frequencies could be contributing to his global bias. However, a spatial frequency bias is unlikely to provide a full account of these results given that the patients showed opposite patterns also when

responding to control (block) letters differing in size but not in critical spatial-frequency components. Also, S.A. showed a decreased sensitivity for high spatial frequencies too relative to the controls, and yet she presented with a local advantage (opposite to controls). An alternative idea is that H.J.A.'s lesion leads to coarsened initial grouping of stimuli, generating a global percept but with reduced local detail. We elaborate on these ideas more in the General Discussion. Whatever the case, the important point is that both patients show increased effects when they are presented with hierarchical forms compared with block letters. This suggests that there are effects of differential saliency of the local and global forms for the two patients. The patients find it difficult to attend to the low saliency aspect of a hierarchical form mainly when there is competition from a higher saliency competing aspect (cf. Mevorach, Humphreys, & Shalev, 2005a, 2005b); this competition is absent when block letters are presented. This differential competition also accounts for why patients show greater interference effects than the controls (albeit in opposite directions in the two patients).

GENERAL DISCUSSION

We have presented data documenting differences in object processing in two types of apperceptive agnosia: form agnosia (patient S.A.) and integrative agnosia (patient H.J.A.). Both patients suffered from impaired object recognition that was perceptual in origin and led to visual/visual-semantic or "don't know" responses in object naming. Both were impaired at figure-ground organization based on edge contours, and both were abnormally affected by stimulus exposure duration. However, in other respects, the object-processing capacities of the patients differed. H.J.A. was worse at identifying animate than inanimate items (see also Riddoch & Humphreys, 1987a; Riddoch et al., 1999), and he was also more impaired at segmenting animate items when they were presented overlapping with other drawings (Section B,

Experiment 1a). In contrast, S.A. was better at identifying animate than inanimate items, especially with reduced exposure durations. In addition to this, S.A. was worse than H.J.A. at segmenting line drawings when the task required matching to a visual sample, and she was worse at contour tracing and at deciding whether pairs of dots were both inside and outside complex, unfamiliar shapes ("amoebae"; Section B, Experiments 1b and 2). Yet, despite this evidence for many aspects of early visual processing being worse in S.A., she was generally better than H.J.A. at recognizing familiar objects (Section A), and her ability to segment overlapping figures showed greater improvement when she was cued to find a particular target (with S.A. performing better than H.J.A. in the verification task; Section B, Experiment 1a). Finally, whilst H.J.A. demonstrated an exaggerated bias towards global processing of hierarchical forms (see also Humphreys et al., 1985), S.A. produced an opposite effect with the same displays, with her performance being biased to local elements (Section B, Experiment 3).

The contrast between these two patients provides the first direct evidence of a qualitative difference in object processing in form and integrative agnosia using the same tests in patients, consolidating the argument for these two forms of apperceptive agnosia being distinct. This is also reinforced by the contrasting dorsal and more ventral medial lesions suffered by S.A. and H.J.A., linking the two forms of agnosia to different underlying neural substrates.

Integrative agnosia

We propose that normal object recognition depends on participants concurrently coding global aspects of shape with local detail about the parts of stimuli (Humphreys & Riddoch, 2006). Previously we have defined integrative agnosia as being due to a problem in this last process, of integrating local parts with more holistic properties of objects. As a consequence, patients have an impoverished visual representation of objects. In addition, due to the poor

part-whole integration, such patients have difficulties in decomposing scenes with complex figure-ground relations; they can misattribute edges between shapes (Giersch, Humphreys, Barthaud, & Landmann, 2006; Giersch, Humphreys, Boucart, & Koviáks, 2000), they group parts incorrectly, and they can oversegment objects with high internal detail (Lawson & Humphreys, 1999; Riddoch & Humphreys, 1987a). This is demonstrated here by H.J.A.'s performance with overlapping line drawings (Section B, Experiment 1), where he frequently made mis-segmentation errors, with this problem being exacerbated when the stimuli had internal detail (Section B, Experiment 1b).

Although H.J.A. is impaired at integrating part with whole information, the present results confirm that he is able to respond to simple global compound letters and indeed shows a stronger global precedence effect than normal participants (Section B, Experiment 3; see also Humphreys et al., 1985). This may reflect a relatively spared ability to respond to low-spatial-frequency components in images, since global precedence can be supported by low-spatial-frequency information (Badcock et al., 1990; Lamb & Yund, 1996; Shulman, Sullivan, Gish, & Sakoda, 1986), though the effects of size even with block letters suggest that low-spatial-frequency dominance does not provide a full account. A further possibility is that there is a coarse initial grouping process supported by his spared early visual cortex, which averages across elements in a nonoptimal manner (for direct evidence see Allen et al., 2007). This can explain the problems that H.J.A. has due to the misassignment of edges in complex scenes, if edge information is pooled inappropriately (Giersch et al., 2000). Whichever is the case, the resulting global representation that H.J.A. is able to form is underspecified and lacking in detailed part information due to the deficit in part-whole integration (see Humphreys & Riddoch, 1987a); as a consequence object recognition is impaired. Indeed, when attempting to identify objects H.J.A. often follows a piecemeal approach in which different parts are not considered together (see

Humphreys & Riddoch, 1987b, for examples). We attribute this to local parts, when undergoing integration with global representations, tending to segment the holistic form and to H.J.A. adopting a strategy of attending to local parts serially, due to his global form representations being underspecified.

Our data also indicate that H.J.A. has problems in identifying animate items (see also Riddoch & Humphreys, 1987a; Riddoch et al., 1999). It is possible that this deficit could reside at several levels of processing, including reflecting a loss of semantic knowledge about animate items (Caramazza & Shelton, 1998; Humphreys & Forde, 2001). We have previously reported that, in the period since his lesion, H.J.A. suffered some degradation of knowledge for animate items (Riddoch et al., 1999). We have attributed this to the importance of perceptual updating of stored visual knowledge and to this being particularly important for classes of stimuli that have many perceptual neighbours and/or stimuli for which perceptual features are central to their stored representations. There are grounds for arguing for both of these last factors being critical for animate items (see Farah & McClelland, 1991; Gaffan & Heywood, 1993; Humphreys & Riddoch, 2003; though see Laws, 2005, for an alternative view). However, we think that a loss of stored perceptual knowledge is unlikely to account for the full pattern of the present data. H.J.A. gave accurate descriptions of the set of animate items that he failed to identify here (Section A). Moreover, H.J.A.'s ability to match objects to sample when figures were overlapping was worse for animate than for inanimate items. This result points to a perceptual contribution to the deficit. The particular perceptual deficit in H.J.A., where there is rapid but coarse coding of global shape along with impaired integration of part information, may be important here. Measures of contour overlap indicate that animate items tend to have similar global shapes, and they also tend to have many common parts (head, body, legs, wings), at least at a coarse level of description (Humphreys et al., 1988). The similarity of the initial coarse description that H.J.A.

derives for different animate items can, in turn, make it difficult for him to identify individual items. This may be particularly the case if he also finds it difficult to isolate parts within the coarse visual description, making him insensitive to the local differences that may help to differentiate different animate items. This problem may be less pronounced for inanimate items if their global structures are less similar. On this account, the category specificity in object recognition demonstrated by H.J.A. is at least partly a function of a visual processing deficit (see also Humphreys & Riddoch, 2003). We return subsequently to consider the relation between H.J.A. and other patients with category-specific deficits for animate items.

Despite the problem in part-whole integration, Experiment 2 (Section B) showed that some aspects of visual processing remain relatively intact for H.J.A.—notably the ability to carry out contour tracing (at least until complex, unfamiliar shapes were overlapping, and the dots to be compared were spaced far apart). This is of some interest because Roelfsema and colleagues (e.g., Roelfsema et al., 2000) have argued that contour tracing depends on feedback from higher level regions in ventral cortex (e.g., area V4) to primary visual cortex, so that tracing can operate across larger regions than those typically covered by the receptive fields of neurons in primary visual cortex. These higher level regions are lesioned in H.J.A. (Allen et al., 2007), so the current data are consistent with tracing being conducted within early visual areas (such as V1), which are spared in his case. For H.J.A., activation in early regions may be supported by feedback from global shape representations coded outside of medial ventral extrastriate cortex (i.e., regions spared in his case), along with voluntary attentional processes in parietal cortex (cf. Corbetta & Shulman, 2002). The linear functions in the time taken by H.J.A. to match increasingly spaced dots are consistent with some degree of serial attentional involvement in the contour-tracing tasks. Note that the estimated rate of these functions was close to those found for the control participants,

indicating intact attentional scanning in this patient (see also Humphreys et al., 1992).

Form agnosia

S.A. showed a primary diagnostic feature of form agnosia—namely an inability to perform the Efron shape-matching task. The data presented here indicate that S.A.'s basic ability to segment shapes was also worse than that of H.J.A., given her poor level of performance in the match-to-sample task with overlapping shapes (Section B, Experiment 1b), and she was very impaired at contour tracing (Section B, Experiment 2). The deficits in tracing a target in a set of overlapping stimuli cannot be simply due to poor eye-hand coordination, since similar impairments arose with contour tracing (where hand responses were not required). These deficits also cannot be attributed to impairments in scanning spatial attention, given that S.A. was able to perform serial visual search efficiently (Section B). One possibility is that the impairments reflect a tendency for S.A. to focus on local image features, making her insensitive to more global properties of shape. For example, focusing on a local part of a shape would disrupt Efron shape matching, where sensitivity to covariation along two dimensions is critical. Similarly, the ability to judge whether two stimuli lie inside or outside an "amoeba" shape requires perception of the global properties of the shape (Section B). Some support for S.A. showing a local bias in shape processing comes from the data on processing hierarchical forms, where she generated a pattern of local bias contradicting the normal profile (Section C).

In contrast to H.J.A., S.A. showed a tendency to find animate items easier to identify than inanimate items, especially when presentation durations were limited. Given that S.A. was able to give accurate descriptions of the stimuli from their names (Section A), and she was also able to list critical visual features (Section B), we think it is unlikely that a semantic deficit plays a major contributory role here. It is possible, though, that a bias towards local processing may be

important. The local parts of many inanimate items tend to be similar (handles, blades, containers), and it is the particular combination of these parts that defines the object (cf. Biederman, 1987). In contrast, the local parts of animate items may have either distinctive shapes (the ears or the nose of an animal) or distinctive textures (the coat of a tiger, the skin of an orange) that enable them to be identified from a part processed in isolation. We have some preliminary evidence for this. We have presented normal participants with line drawings of inanimate and animate items where only one local area is presented at a time (using a moving-window technique). An advantage for animate over inanimate items emerges under these conditions (Demeyere, Humphreys, & Riddoch, 2008). The evidence for S.A.'s advantage for animate items emerging under short presentation conditions would also fit with the idea that her problems are exacerbated when she has only to code a few parts of stimuli.

Top-down processes

One other substantial contrast between S.A. and H.J.A. is their ability to use top-down information to facilitate object recognition. Despite performing worse at several tasks tapping early perceptual abilities, S.A. was better at object identification than was H.J.A. (Section A), and she benefited more from top-down cueing with overlapping shapes (Section B, Experiment 1a). This last result is striking and points to there being a distinction between bottom-up and top-down contributions to object recognition—and, notably, good top-down processes can help to compensate for a bottom-up processing impairment. The data reported in Experiment 1 also indicate the way in which top-down information was beneficial for S.A. With overlapping shapes, S.A. denoted different distinctive features in objects relative to when the objects were presented alone or described verbally. This suggests that top-down knowledge did not enable S.A. to segment the overlapping shapes, since we would predict that she should select the same critical features in all

cases. Instead, it appears that S.A. was able to fit top-down knowledge in a flexible manner to parts of objects that were not overlapping with other stimuli. This “fitting” of perceptual features to stored knowledge occurred even when the available features were not the distinctive parts that could normally define an object. Moreover, given the differential sites of the lesions in H.J.A. and S.A., we also propose that top-down processes for visual object recognition are mediated by medial ventral extrastriate cortex extending to posterior temporal cortex (lesioned in H.J.A.). This fits with data on brain imaging reported by Dolan et al. (1997). They imaged participants when presented with ambiguous figures either before or after the participants saw disambiguating visual information and found increased activation in the fusiform gyrus when the disambiguating visual information could be used in a top-down manner to interpret the stimuli. Our data suggest that the fusiform gyrus, perhaps along with other medial ventral extrastriate regions, is necessary for top-down effects to be implemented.

Relations to other patients and evidence from brain imaging

To what extent do our arguments for a contrast between integrative and form agnosia, and for the functional consequences of the visual processing deficits, hold across other patients? The ability to process local and global elements of form has been examined now in a small number of apperceptive agnostic patients. The well-documented form agnostic patient D.F., like S.A., appeared to show a local bias in interpreting hierarchical stimuli. Thus Milner et al. (1991) report that DF tended to focus on the local elements in forms of this type and found it difficult to perceive the global shape. Similar results have been reported by Charnallet et al. (1996), Piccini, Lauro-Grotto, Del Viva, and Burr (2003), and Ricci et al. (1999). Behrmann and Kimchi (2003) examined the report of local and global shapes in two patients described as integrative agnosics on the basis of the patients showing reasonable

copying, a spared ability to match objects across views but an impaired identification of overlapping shapes and visual/visual-semantic errors in picture naming. One of these patients, like H.J.A., showed a global advantage when identifying hierarchical forms but the other produced a local advantage. At present the reason for this last result is unclear, although, as we have noted above, patients may focus attention on local parts when the global representation is impoverished, so it is possible that this strategy might be applied with hierarchical stimuli not forming a particularly strong global shape even for control participants. We also note that the patients described by Behrmann and Kimchi (2003) had more anterior temporal lesions than H.J.A., and this may be critical. If the posterior lesion in H.J.A. leads to coarse grouping, with a loss of part-detail, then he may tend to show a stronger global precedence than is the case in patients with more anterior damage. Indeed, other evidence suggests that the right anterior temporal lobe is important for focusing attention on the global aspects of form (Lamb, Robertson, & Knight, 1990; Robertson, Lamb, & Knight, 1988). Thus it is possible that lesions in this region lead to performance being biased to local shapes as Behrmann and Kimchi (2003) observed. On this view, such patients may suffer an attentional bias towards local forms, which in turn leads to problems with other perceptually difficult stimuli (e.g., overlapping forms). In contrast, patients such as H.J.A. and S.A., with more posterior occipital lesions, have difficulty either in computing integrated part-whole representations (H.J.A.) or in computing local forms (S.A.) and suffer perceptual deficits for these reasons. We note too that the patients reported by Charnaliet al. (1996) and Milner et al. (1991) were both impaired at the Efron shape-matching test (data are not reported for the other patients), and their pattern of local dominance fits with the pattern presented by S.A. It would clearly be of interest to assess whether the other cases in the literature also have difficulty with contour-tracing tasks, which we link to attending very locally to the parts of patterns.

As noted in the Introduction, patients similar to S.A., who present with local dominance and poor perception of basic forms, have been reported with a variety of lesions. For example, the case of Charnaliet al. (1996) had bifrontal lesions and a right parieto-occipital lesion extending into the white matter. Piccini et al.'s (2003) case was documented with degenerative changes affecting the right angular gyrus, while D.F. is reported with damage to the Lateral Occipital Cortex (LOC) plus posterior parietal damage. Patient J.W., reported by Vecera and Behrmann (1997), who also showed poor performance in the Efron task, had bilateral occipital along with right parietal damage. In the other cases with local bias, either no damage has shown on scan (Behrmann & Kimchi, 2003) or diffuse damage was likely (Ricci et al., 1999). With the possible exception of D.F., these patients all appear to have suffered relatively dorsal involvement of occipital-parietal cortex, and even in D.F.'s case there was some parietal damage in addition to bilateral lesions to LOC. Hence there is a case here for the argument that dorsal occipital-parietal damage, evident in a circumscribed way in patient S.A., at least contributes to the local bias and impaired shape perception in these patients—even if damage to other regions (e.g., LOC) also plays a role. S.A.'s case, though, demonstrates that damage to LOC is not necessary to generate form agnosia.

A local bias in responding to hierarchical forms has also been noted in patients with Balint's syndrome following bilateral parietal damage (e.g., Huberle & Karnath, 2006; Jackson, Swainson, Mort, Husain, & Jackson, 2004; Karnath, Ferber, Rorden, & Driver, 2000; Shalev, Humphreys, & Mevorach, 2005). Such patients show an additional impaired ability to shift attention across space (Friedman-Hill et al., 1995; Humphreys et al., 2000) and only appear aware of single objects at a time. S.A. did not manifest such signs of simultanagnosia. As we have noted, she showed a normal rate of serial search for colour-form conjunctions, and in other tests we failed to find evidence of extinction with letters presented simultaneously for 50 ms (cf. Kinsbourne & Warrington, 1962). However it

may be that, in simultanagnosic patients, we witness the presence of two deficits due to the typically extensive parietal lesions—a problem in attending to global form (as in S.A. here) and a problem in shifting attention. This would still fit with the argument for a role of dorsal occipital-parietal regions in attending to global shape. It is also of interest to note that simultanagnosic patients can show some problems in object recognition, despite having more ventral visual cortex intact, and their recognition errors often reflect the parts and/or surface textures of objects (Riddoch & Humphreys, 2004). Again there is a suggestion of a local bias in their identification performance.

Riddoch and Humphreys (2004) further reported that their simultanagnosic patients were relatively better at identifying animate than inanimate items, despite, like S.A. and H.J.A. here, having relatively good semantic knowledge about objects. In that paper we suggested that this non-semantic category effect may reflect some residual holistic perception in these patients. However, given S.A.'s severe problems in holistic processing not only with hierarchical forms but also with relatively simple contour-tracing tasks, we suggest that our earlier account is probably incorrect. It is more consistent to argue that these patients were locally biased in object identification as well as in other aspects of form processing, and that animate items were easier to identify due to their having identifiable local parts and textures. In contrast, inanimate items are difficult to identify because their local parts, computed in isolation, are not diagnostic of the whole object's identity—the relations being the parts being critical in this case. The opposite pattern then arises in a patient such as H.J.A. who has initial access to global representations of objects, but these holistic representations are not embellished by part-details. We suggest that animate items are more difficult for such patients to identify because they have similar global forms.

Recently Thomas and Forde (2006) have made a different argument to the one we have just voiced, based on a single case study (patient D.W.) who showed a local bias with hierarchical

stimuli and a category-specific deficit for animate items. They argue that D.W.'s local bias led to the category-specific impairment. However, as we have noted (Humphreys & Riddoch, 2008), D.W. had impaired semantic knowledge for animate items, as evidenced by his poor drawing from memory, his impaired verbal definitions, and a deficit in naming animate items from verbal definitions (see Riddoch & Humphreys, 1992; Thomas, Forde, Humphreys, & Graham, 2002, for earlier descriptions of his case). Hence the argument presented by Thomas and Forde rests on an association between two potentially separable effects: a bias on perception/attention and impairment in semantic memory. The problem here is that a deficit for animate items in semantic memory could override any differential perceptual effect favouring animals. Here we too make an argument based on association, but an association in the opposite direction to that proposed by Thomas and Forde. We have reported one case where a bias to global selection co-occurs with a deficit with animate items (H.J.A.), and another where a bias to local selection co-occurs with a deficit with inanimate stimuli (S.A.). This double dissociation, using the same stimuli, indicates at the very least that there is no necessary relation between a local bias in perception and a deficit for naming animate stimuli, contrary to Thomas and Forde. In addition, the associations we report with our patients are stronger than the one found by Thomas and Forde, since our patients did not have semantic problems and thus problems at "late" as well as earlier stages of object recognition. For H.J.A. and S.A., it is more difficult to make an argument that opposite effects, at different stages, cancel each other out. In contrast, patients such as S.A. and H.J.A. do not have a semantic deficit, making a clearer case for a relation between their perceptual deficit and the category effect on object identification. Furthermore, patients such as H.J.A. demonstrate that there can be a global bias in perception along with selectively poor identification of animate items (see Humphreys et al., 1985; Riddoch & Humphreys, 1987a, for prior evidence), indicating no necessary relation

between a local bias and a deficit for naming animate items. We go further than this and propose there is no relation.

A final point concerns the link between work using neuroimaging and our argument for local and global biases in perception and attention being mediated, respectively, by inferior medial ventral extrastriate cortex and more dorsal occipital-parietal cortex. There is evidence for the perception of local parts in hierarchical figures being mediated by inferior medial occipital cortex, particularly on the left (e.g., Fink, Marshall, Halligan, & Dolan, 1997, 1999). Evidence for the involvement of more dorsal occipital-parietal areas in the perception of global forms is less clear (Heinze, Hinrichs, & Scholz, 1998; Weissman & Woldorff, 2005; Yamaguchi, Yamagata, & Kobayashi, 2000). In a recent paper, Himmelbach, Erb, Klockgether, Moskau, and Karnath (in press) have reported imaging data from a simultanagnosic patient, separating trials where a global hierarchical form was perceived from those where it could not be reported. They report that this contrast between seeing and not seeing the global form was associated with activity in dorsal occipital cortex/ventral precuneus. These authors suggest that activity in this region is typically not seen in subtractions between responses to global and local levels of hierarchical forms because normal participants perceive the global form even when set to select local elements. However, as their patient sometimes failed to perceive the global form and detected only local elements, the role of the region in the conscious discrimination of global forms could be revealed. The data on S.A. are entirely consistent with this proposal.

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