Focal hemisphere and visuoperceptual categorization¹

EDOARDO BISIACH³, ERMINIO CAPITANI, AND HANS SPINNLER

From the Neuropsychology Centre, University of Milan, Italy

SYNOPSIS Visuoperceptual categorization was investigated in patients with unilateral brain damage by a task in which meaningless shapes had to be classified with reference to a number of prototype patterns. Right brain-damaged subjects with visual field defect turned out to have a narrower categorization span. As this outcome seems to be scarcely consonant with a lower level disorder of visual processing, a major competence of the right hemisphere is suggested for visuoperceptual categorization.

In the past 20 years extensive research on visuoperceptual disorders after focal brain damage has shown that injury to the right cerebral hemisphere is especially detrimental to performance on several tasks involving processing of visual stimuli. Individual findings, however, have so far proved to be scarcely susceptible of a unitary interpretation. Isolated explanatory essays relating interhemispheric asymmetries in perception to stimulus characteristics, either physical (Meier and French, 1965; De Renzi and Spinnler, 1966; Milner, 1967) or semantic (Kimura, 1963; Milner, 1967; De Renzi *et al.*, 1969), or to different strategy along the analytic-holistic dimension of visual processing (Levy-Agresti and Sperry, 1968; Nebes, 1971; Levy *et al.*, 1972) are not exempt from criticism and/or cannot cope with the whole body of empirical findings. Bisiach and Faglioni's (1974) data have indeed challenged the view according to which right brain-damaged are more impaired than left brain-damaged patients in visual processing of complex patterns. On the other hand, an investigation by Basso *et al.* (1974) on the susceptibility of unilateral brain-damaged patients to the Mueller-Lyer illusion failed to confirm the

alleged holistic attitude of the right hemisphere in visual perception. A more extensive exploration of basic cognitive operations in unilateral brain-damaged patients is therefore required. Warrington and Taylor (1973) have recently made a nice point by showing that right posterior brain-damaged patients performed poorly on an identification task of objects displayed in unconventional views, so that their shapes bore no physical similarity to the shape of their conventional representations. With reference to this task, which was essentially one of guessing the meaning of ambiguous patterns, the term of 'perceptual classification' has been employed by Warrington and Taylor in a somewhat comprehensive conceptualization. In the context of the present paper, the concept of perceptual categorization will, on the contrary, be restricted to the ability, tested by us in unilateral brain-damaged patients, of processing sensory information so as to classify meaningless shapes according to their similarity to a given set of prototypes, independent of semantic identification and without the recognizable logical rules which characterize conceptual categorization (Hunt, 1962). The latter seems to be ruled by the left hemisphere, as shown by investigations employing the Weigl's Sorting Test (McFie and Piercy, 1952; McFie, 1960; De Renzi *et al.*, 1966). Conversely, right brain-damaged patients with visual field defects exhibited, in our study, a poorer performance on perceptual categorization.

¹ Research supported by grant no. 71.00783.04 of the Consiglio Nazionale delle Ricerche.

² Preliminary data were presented at the meeting of the European Brain and Behaviour Society, Rotterdam, 1973.

³ Address for correspondence: Centro di Neuropsicologia dell'Università di Milano, Clinica delle Malattie Nervose e Mentali, Via F. Sforza, 35–20122 Milano, Italy.

(Accepted 24 June 1975).

FIG. 1 The eight prototypes and some of the distortions used in the experiment.

METHODS

SUBJECTS The subjects were right-handed normal control (C) and unilateral brain-damaged (BD) patients admitted to the Clinic for Nervous and Mental Diseases of the University of Milan as in- or outpatients from May 1971 to March 1973; BD were screened for the presence of unilateral brain damage according to the standard criteria in use at our centre (De Renzi and Faglioni, 1965), clinical findings being supplemented by EEG, radiological, and isotope scan investigations. About 15% of the BD had to be discarded owing to vigilance disorders, immobility, or extremely severe aphasia. Within the

group of discarded patients there was no significant difference between the frequencies of left and right BD. None of the subjects had any noticeable defect of visual acuity, though this was not formally assessed. As to the aetiology, 84% suffered from cerebrovascular attacks, 13% had a neoplastic disease, and 2% were traumatic. These percentages did not vary significantly across the two hemispheric groups.

The BD group was subdivided according to absence/presence of visual field defect (VFD-VFD+) on confrontation (Bisiach, and Faglioni, 1974). Subjects were therefore distributed in the following

five groups: (1) C, $N=30$. (2) Left BD VFD- (L-), $N=57$. (3). Left BD VFD+ (L+), $N=19$. (4) Right BD VFD- (R-), $N=29$. (5) Right BD VFD+ (R+), $N=24$.

STIMULI Eight 24-point random shapes drawn from Vanderplas and Garvin's (1959) sample were selected as prototype patterns. From each prototype a family of 15 progressive distortions (Fig. 1) were generated by means of an optical device (fish-eye lens). The size of the eight prototypes and of the 120 distorted patterns was about 10×10 cm; they were printed in black on a white background and mounted on 12×12 cm aluminium plates.

PROCEDURE Four prototypes were displayed by means of an exposor. The group of the prototypes first presented was balanced across subjects in each experimental group. In order to avoid verbal instructions about the task to be performed, we proceeded as follows. Twenty-four distortions (three from each of the eight families: sixth, eighth, tenth) were successively shown to the subjects in random order for a short inspection and then either ostensibly placed in one of the boxes of the exposor beside the corresponding prototype, or discarded if the pattern did not belong to one of the four families of which the prototype was exposed. After a few such trials, the subject was invited by gestures to allocate the patterns himself. During this demonstration stage, the experimenter helped the subject

whenever he manifested uncertainty and corrected his errors.

As soon as these preliminaries were completed, the 120 distorted patterns were administered to the subjects according to a fixed random schedule. A second session of the experiment was then run in which the four prototypes formerly exposed were replaced by the four remaining. The overall number of trials was therefore 240. The subjects' responses were recorded on an individual protocol and classified according to the following four categories:

1. Correct attribution of a pattern to the corresponding prototype.
2. Correct rejection of a pattern the prototype of which is not exposed.
3. Incorrect attribution of a pattern to the prototype of another family. These responses were further split as follows:
 - Type (a): incorrect attribution of a pattern the prototype of which is exposed.
 - Type (b): incorrect attribution of a pattern the prototype of which is not exposed.
4. Incorrect rejection of a pattern the prototype of which is exposed.

Unlimited time was granted for the response. No feedback was given of the correctness of choices.

RESULTS

ANALYSIS OF CATEGORIZATION SPAN Figure 2 reports the percentage of correct attributions

FIG. 2 *Perceptual categorization span. Percentage of correct attributions as function of degrees of pattern distortion.*

TABLE 1

PERCEPTUAL CATEGORIZATION SPAN: MEANS OF CORRECT ATTRIBUTIONS, ADJUSTED FOR AGE AND EDUCATIONAL LEVEL

Control group		BD		
		Left	Right	
89.9	VFD-	87.2	87.3	87.2
	VFD+	87.3	77.9	82.6
		87.2	82.6	84.9

made by the five experimental groups as a function of the degree of distortion of the pattern. It shows that in all groups the number of errors increased as the pattern was more dissimilar from the prototype. The means of correct attribution made by the five groups (Table 1) were compared by a covariance analysis (Scheffé, 1959), concomitant variables being age and years of schooling (Table 2). Controls

TABLE 2

PERCEPTUAL CATEGORIZATION SPAN: COVARIANCE ANALYSIS

Source of variability	DF	F	P
BD groups vs. controls	1/152	3.909	< 0.05
BD groups	3/152	4.075	< 0.01

turned out to score higher than BD ($P < 0.05$). As the means of the four BD groups were found to be significantly different ($P < 0.01$), multiple comparisons were carried out using Scheffé's method (1953). From this analysis (Table 3) the R+ group, which showed the lowest scores, turned out to be significantly different from each of the other BD groups.

ERRORS ANALYSIS Percentages of errors (incorrect rejections and type (a) and (b) incorrect attributions) made by the five experimental groups and related to the 120 trials in which each kind of error could have occurred are entered in Table 4. It is apparent from this Table that the categorization span is almost uniquely influenced

TABLE 3

PERCEPTUAL CATEGORIZATION SPAN MULTIPLE COMPARISONS

	BD		
	Left VFD+	Right VFD-	Right VFD+
Left BD, VFD-	$F < 1.0$	$F < 1.0$	$F = 3.501$ ($P < 0.025$)
Left BD, VFD+	—	$F < 1.0$	$F = 2.684$ ($P < 0.025$)
Right BD, VFD-	—	—	$F = 2.777$ ($P < 0.025$)

TABLE 4

PERCENTAGES OF ERRORS

	Control group	BD			
		Left		Right	
		VFD-	VFD+	VFD-	VFD+
Incorrect rejections	24.75	27.00	26.75	26.75	33.75
Incorrect attributions					
Type (a)	0.30	0.33	0.53	0.46	1.35
Type (b)	0.30	0.16	0.70	1.78	1.70

by the incorrect rejections. On type (a) and type (b) incorrect attributions two independent non-parametric analyses were carried out.⁴

Type (a) incorrect attributions proved to differ significantly across the five experimental groups (overall $\chi^2 = 657.47$; $df = 4$, $P < 0.0005$) and between left and right BD (partitioned $\chi^2 = 16.41$; $df = 1$, $P < 0.0005$). Type (b) incorrect attributions were also found to differ across the five experimental groups (overall $\chi^2 = 1560.46$; $df = 4$, $P < 0.0005$) and between left and right BD (partitioned $\chi^2 = 101.84$; $df = 1$, $P < 0.005$).

DISCUSSION

The results we have reported show that the ability to categorize visual meaningless shapes according to their similarity to a prototype

⁴ As the incorrect attribution scores for each subject had mainly the value of 0, the following more frequent values being 1 and 2, their distribution, obviously not normal, was not of the Poisson's type either. Considering the set of answers given by each subject to be invariably defined by four components (correct attributions, incorrect attributions, correct rejections, and incorrect rejections), we decided to compare across the experimental groups, by means of a χ^2 , the partition between the frequency of one of these events (incorrect attributions) and that of the three others pooled together, using the method described by Maxwell (1961).

pattern is especially reduced after injury to the posterior regions of the right cerebral hemisphere. Uncontrolled attributions of a shape to a rival prototype (type (a) incorrect attributions) could have spuriously inflated differences in categorization span by subtracting an item from its own category; this effect, however, proved to be negligible in every experimental group. On the other hand, the greater incidence of incorrect attributions in the R+ groups rules out an interpretation of these patients' behaviour in terms of a more rigid criterion in setting their limit for the acceptance of an item into one of the available categories.

The question arises as to whether we are really dealing here with a disorder of categorial behaviour, the obvious alternative being that of a lower level disorder of visual pattern processing. We are inclined to reject the latter explanation on the basis of the outcome of a recent investigation on Vanderplas and Garvin's random shapes recognition in brain-damaged patients (Bisiach and Faglioni, 1974): this kind of task was not specifically affected by right hemisphere lesions involving visual pathways; actually R- and R+ scored better than L- and L+ patients, respectively. We would therefore advocate the failure on visuoperceptual categorization of this kind of stimulus as a distinct feature of cognitive organization in R+. It should be parenthetically noted that the different outcomes of recognition and of classification of random shapes suggest that task requirements can be even more crucial than stimulus characteristics in bringing about behavioural asymmetries related to the locus of a brain lesion.

In conclusion, it is suggested that a weakness in perceptual categorization of visual stimuli ensues from right brain lesions involving central optic pathways. This datum, along with those of Warrington and Taylor (1973), hints at an impairment of right brain-damaged patients' cognitive functions beyond the stage where the internal representation of the stimulus is structured. The narrowing of visuoperceptual categorization span in these patients does not seem to be connected with a more conservative response criterion. The possibility can therefore be envisaged that generalization processes (within categories) and discrimination processes (between categories) are better performed by the

right hemisphere. The question can further be raised as to whether the two hemispheres formulate similarity judgments according to different algorithms, a question which undoubtedly warrants further inquiry.

The reading of and helpful comments on this manuscript by Sue and John Oxbury are gratefully acknowledged.

REFERENCES

- Basso, A., Bisiach, E., and Faglioni, P. (1974). The Mueller-Lyer illusion in patients with unilateral brain damage. *Cortex*, **10**, 26-35.
- Bisiach, E., and Faglioni, P. (1974). Recognition of random shapes by patients with unilateral lesions as a function of complexity, association value and delay. *Cortex*, **10**, 101-110.
- De Renzi, E., and Faglioni, P. (1965). The comparative efficiency of intelligence and vigilance tests in detecting hemispheric cerebral damage. *Cortex*, **1**, 410-433.
- De Renzi, E., Faglioni, P., Savoiardo, M., and Vignolo, L. A. (1966). The influence of aphasia and of hemispheric side of the cerebral lesion on abstract thinking. *Cortex*, **2**, 399-420.
- De Renzi, E., Scotti, G., and Spinnler, H. (1969). Perceptual and associative disorders of visual recognition. Relationship to the side of the cerebral lesion. *Neurology (Minneapolis)*, **19**, 624-642.
- De Renzi, E., and Spinnler, H. (1966). Visual recognition in patients with unilateral cerebral disease. *Journal of Nervous and Mental Disease*, **142**, 515-525.
- Hunt, E. B. (1962). *Concept Learning: an Information Processing Problem*. Wiley: New York.
- Kimura, D. (1963). Right temporal lobe damage. *A.M.A. Archives of Neurology*, **8**, 264-271.
- Levy, J., Trevarthen, C., and Sperry, R. W. (1972). Perception of bilateral chimeric figures following hemisphere deconnection. *Brain*, **95**, 61-68.
- Levy-Agresti, J., and Sperry, R. W. (1968). Differential perceptual capacities in major and minor hemispheres. *Proceedings of the National Academy of Sciences of the United States of America*, **61**, 1151.
- McFie, J. (1960). Psychological testing in clinical neurology. *Journal of Nervous and Mental Disease*, **131**, 383-393.
- McFie, J., and Piercy, M. F. (1952). The relation of laterality of lesion to performance on Weigl's sorting test. *Journal of Mental Science*, **98**, 299-305.
- Maxwell, A. E. (1961). *Analysing Qualitative Data*. Methuen: London.
- Meier, M. J., and French, L. A. (1965). Lateralized deficits in complex visual discrimination and bilateral transfer of reminiscence following unilateral temporal lobectomy. *Neuropsychologia*, **3**, 261-272.
- Milner, B. (1967). Brain mechanisms suggested by studies of temporal lobes. In *Brain Mechanisms underlying Speech and Language*. Edited by C. H. Millikan and F. L. Darley. Grune and Stratton: New York.
- Nebes, R. D. (1971). Superiority of the minor hemisphere in commissurotomy man for the perception of the part-whole relations. *Cortex*, **7**, 333-349.

- Scheffé, H. (1953). A method for judging all contrasts in the analysis of variance. *Biometrika*, **40**, 87–104.
- Scheffé, H. (1959). *The Analysis of Variance*. Wiley: New York.
- Vanderplas, J. M., and Garvin, E. A. (1959). The association value of random shapes. *Journal of Experimental Psychology*, **57**, 147–154.
- Warrington, E. K., and Taylor, A. M. (1973). The contribution of the right parietal lobe to object recognition. *Cortex*, **9**, 152–164.