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Recognition of Random Shapes in Brain-Damaged Patients*

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Summary. In two experiments the hypothesis was tested that left hemisphere-damaged patients and especially those with aphasia are impaired in the recognition of meaningless random shapes because they fail to attribute a meaning to the shapes. In a multiple choice recognition task, left hemisphere-damaged patients with aphasia and left and right hemisphere-damaged patients without aphasia were shown complex random shapes together with either a pictorial cue (experiment I and II) or a dotted drawing of its outline on which more or less outstanding parts were specially marked (experiment I). In experiment I no difference between conditions or groups emerged. In experiment II aphasics and left hemisphere-damaged patients without aphasia were generally inferior to right hemisphere-damaged controls and performed significantly better when a pictorial cue was given than when it was absent, however only when the conditions were given in a certain order.

Key words: Aphasia – Right hemisphere damage – Recognition – Random shapes

Introduction

Considerable evidence has accumulated that not only the right hemisphere (RH) but also the left hemisphere (LH) contributes significantly to the mental representation, integration and retention of visual stimuli (De Renzi 1982; Sergent 1983). In some studies the recognition of meaningless visual patterns such as scrawls, shape silhouettes, or abstract geometrical designs was found to be better preserved in LH-damaged (LHD) than in RH-damaged (RHD) patients (Kimura 1963; Riege et al. 1980). However, in other studies LHD patients did not perform better (Butters et al. 1970; Kimura 1966) or even performed at a lower level than RHD patients (Boller and De Renzi 1967; Gainotti et al. 1978; Miceli et al. 1981).

Likewise, in some studies with normal subjects a left visual field/RH (LVF-RH) advantage emerged for the recognition of such stimuli (Bevilaqua et al. 1979; Hatta 1982) while in other studies no difference (Kimura 1966; Shai et al. 1972) or a right visual field/LH (RVF-LH) advantage was found (Hines 1975).

It is still unclear which particular factors determine an RH or LH advantage in visual-spatial tasks. However, the results of the methodologically relatively homogeneous group of studies investigating the recognition of the random shapes constructed by Vanderplas and Garvin (1959a, b) suggest that the properties of the stimuli to be retained, their complexity and their similarity to familiar objects as measured by their association value, as well as procedural aspects of the task, such as the exposure time and the retention interval, are relevant.

In studies using complex random shapes (shapes with 16 to 24 points) with low association values, LHD rather than RHD patients were found to perform worse, especially when fairly short exposure times (0.5 or 2 s) were chosen, or when, after relatively long presentations (5 s), a delay interval (5 s) was introduced (Bisiach and Faglioni 1974; Bisiach et al. 1979). In recognizing simple random shapes (shapes with 4 to 6 points) and complex shapes with

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a high association value, however, LHD patients were only slightly inferior to RHD (Bisiach and Faglioni 1974). Interestingly, Bisiach and Faglioni (1974) found, like Boller & DeRenzi (1967) and Gainotti et al. (1978), that among the LHD patients those with aphasia were the most impaired on these tasks.

Visual half-field studies with normals are basically in good agreement with these findings. An LVF-RH superiority has been obtained only for shapes of medium complexity (12-point shapes; Birkett), whereas complex shapes have either been recognized with similar accuracy in both visual fields (Hellige 1978; Polich 1982), like simpler shapes with 6 to 8 points (Fontenot 1973; Krynicki 1974), or they have tended to be recognized better in the RVF (Hellige and Cox 1976; Krynicki 1974; Pollich 1982), as was found for the simplest shapes with 4 points (Hannay et al. 1976). There is also some indication that with a longer retention interval LH processing is superior. With a delay of 10 s between stimulus presentation and recognition test, the LVF-RH advantage for 12-point shapes vanished (Birkett 1978) or even turned into an RVF-LH advantage (Hannay et al. 1976).

In addition, Hannay et al. (1981) and Dee and Hannay (1981) obtained a shift towards an RVF-LH advantage for the recognition of 12-point shapes in subjects who had originally shown an LVF-RH advantage for these shapes in a delayed (8 s) same-different recognition task, when labels referring to objects suggested by the shapes had to be learned and used for their subsequent identification.

Traditionally, an RVF-LH advantage in normals or a specific deficit of LHD patients in a nonverbal task is assumed to indicate that the task is solved by verbal mediation (Bradshaw and Nettleton 1981; Brewer 1969). Accordingly, Hannay et al. (1981) and Dee and Hannay (1981) attributed their findings to the verbal requirements of the task and suggested that the LH contributes to the processing of complex visual patterns only when its language functions are involved. According to this view the LH advantage obtained in normals and the specific impairments obvserved for LHD patients following increasing stimulus complexity or longer retention intervals might be due to a greater stability and reliability of verbal codes in contrast to visual-imagery codes.

A different interpretation, however, is suggested by a variety of psycholinguistic studies (Ellis 1973; Nagae 1977) demonstrating that verbal labeling facilitated subsequent recognition of random shapes only when the labels allowed the shape to be related to some available concept. Attaching labels that were meaningful but did not refer to an object resembling the shape, enhanced the recognition performance only slightly or not at all, whereas the effect of shape-related representative labels could be observed even when the label itself was no longer retrievable. Apparently the facilitative effects of labeling are due less to the use of the label as a memory code than to the labels suggesting a conceptual category which allows the shape to be encoded in a unique and integrated way, or directing attention towards distinctive features of the shape suggested by the label.

Following this interpretation, Boller and De Renzi (1967 and Bisiach and Faglioni (1974) claimed that LHD patients, especially those with aphasia, are impaired in the recognition of complex visual patterns not because of their language impairments but because of difficulties in detecting a resemblance between the meaningless shapes and familiar figures. Hence these patients fail when trying to attribute a meaning to the shapes. Sergent (1982), in a critical discussion of the Hannay et al. (1981) results, pointed out that attaching a label requires the unique representation of a form. She suggested that the LH, independent of its language functions, is superior to the RH in performing the detailed visuo-spatial processing necessary to obtain the accurate and complete encoding which is a prerequisite for a unique and integrated stimulus representation.

These assumptions were examined in two experiments where LHD patients with aphasia and RHD patients had to recognize random shapes in a multiple choice task, the shapes being presented to them either without any cue or together with a picture of an object suggested by the shape. In addition, experiment I required the recognition of random shapes each of which had been presented together with a dotted drawing of its outline on which more or less outstanding parts of its contour were specially marked. In experiment II LHD patients without aphasia were also tested.

It was assumed that the cues would facilitate the detection of resemblance between a meaningless shape and a representational figure or would direct attention to specific parts of the shapes, thus making it easier to find a semantic interpretation for the complex meaningless patterns. Hence, if it is true that the impaired retention of complex meaningless stimuli in aphasics and perhaps also in nonaphasic patients with LHD is due mainly to deficient conceptual encoding, then these patients should profit more than RHD patients from cues facilitating the semantic integration of such stimuli.

Experiment I

Method

Material and Procedure. The stimuli consisted of 60 complex random shapes, 30 with 16 points and 30 with 24 points; 22

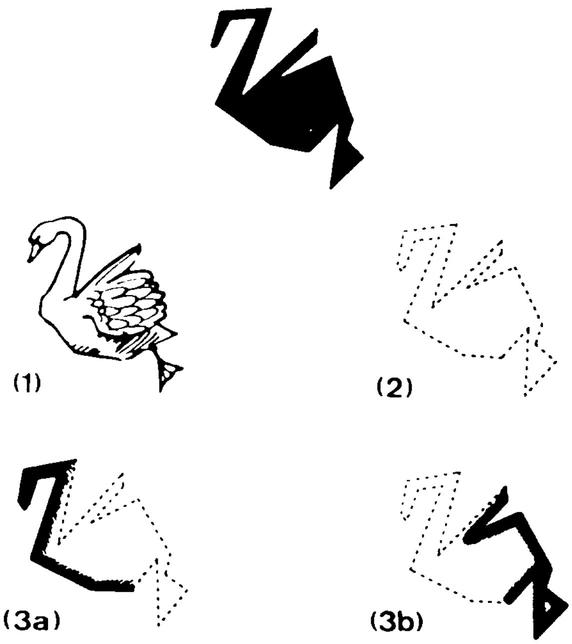

Fig. 1. Examples of stimuli used in the different conditions: *(1)* pictorial cue, *(2)* no cue, *(3a)* marking outline cue (most useful), and *(3b)* marking outline cue (least useful)

shapes with 16 points and 25 shapes with 24 points were taken from Vanderplas and Garvin (1959a). As the 16-point shapes, numbers 6, 9, 10, 12, 13, 15, 22, 24, and the 24-point shapes, numbers 1, 4, 5, 8, 24, of these authors did not yield themselves to a corresponding unique object drawing, 8 16-point shapes and 5 24-point shapes were constructed anew following the method of these authors.

There were three conditions of stimulus presentation: 20 of the 60 target shapes were presented to each subject (1) together with a dotted outline drawing of the shape (no cue), (2) together with an object drawing, the contour of which closely resembled that of the respective random shape (pictorial cue), and (3) together with a dotted outline drawing of the shape with one part marked (marking outline cue), the marking being assumed to direct attention to either unique or common features of the shape (see Fig. 1).

In a pilot study 50 students had been asked to rate five different markings of each contour with respect to how well the marked parts might facilitate the recognition of the random shapes. Marking was carried out by doubling the contour with a thick red line, connecting 5 or 6 points in the 16-point shapes and 7 or 8 points in the 24-point shapes. For only 36 of the 60 shapes did a χ^2 test show a significant difference among the five different markings. Therefore under all three conditions 12 shapes were presented which had been rated as having an outstanding part useful for the retention of the shapes, and 8 shapes were given for which this was not the case. Furthermore, under the third condition half of the 12 shapes with an outstanding feature were presented with the marking rated as most useful while the other half was given with the marking rated as least useful to facilitate recognition (see Fig. 1: (3a) and (3b)). For the other shapes, the marking halfway between most and least preferred was retained.

All the drawings ranged from 4 to 5 cm in size and were mounted on slides. In all conditions the pictorial cue or one of the two kinds of outline drawing was first projected for 3 s, immediately followed by a presentation together with the respective random shape for another 3 s. The different conditions followed one another in random order with the sole restriction being that the same condition occurred in no more than three successive trials. The 16-point and 24-point shapes and shapes of different association value were evenly distributed across the three conditions.

In addition to the 60 experimental trials subjects were given 9 practice and instruction trials. They were instructed to identify each random shape in a multiple choice display after a short time interval had elapsed. They were told to pay attention to the cue stimuli as these might either help find a resemblance between the random shape and a known object, or help them to memorize the shape by emphasizing a part of its contour.

For each of the 60 target shapes a recognition sheet was constructed, showing the target shape together with 7 distractors. The 8 stimuli were arranged in two columns on a white sheet of paper, 10.5×29.9 cm in size. Following Vanderplas and Garvin (1959b) and Ellis and Feuge (1966), 7 shapes were generated for each target with 3 degrees of similarity. Each of the 16 points of the target shape was moved randomly either up, down, right, or left either 2 mm (2 distractors), 3 mm (3 distractors) or 4 mm (2 distractors). The new points were connected with straight, nonintersecting lines.

The target shapes were presented equally often in the lower and upper part, and on the left and right sides of the recognition sheet.

Following the presentation of each shape and a delay of 3 s, the recognition sheet was placed in front of the subject who then had to point to the shape previously seen. An error was recorded whenever one of the distractors was chosen instead of the target shape, or when there was no reaction within 60 s.

Subjects. The subjects were 60 aphasics (31 male, 29 female) and 27 RHD controls (18 male, 9 female). All patients were native German speakers, with an age ranging from 18 to 68 years (mean = 44.4) and all were right handed according to the Edinburgh Inventory (Oldfield 1971). All subjects had lesions restricted to one hemisphere according to clinical information, CAT scans, and EEG records. For the aphasic group only those patients were accepted who were classified as aphasics with 100% aposteriori probabilities on the Aachener Aphasie Test (Huber et al. 1983). According to this test 12 patients were classified as amnesic, 21 as Broca's, 18 as Wernicke's, and 9 as global aphasics.

Aphasics and RHD controls were comparable with respect to age and duration of illness ($0.11 \leq z \leq 1.49$; $P > 0.10$; z-values based on Mann-Whitney U tests), etiology (relative number of vascular and traumatic cases), and level of occupation and education ($0.04 \leq \chi^2 \leq 2.84$; $P > 0.20$).

Results

Since there were no differences between the aphasic subgroups in any analyses, the four groups of aphasics were combined and compared to the RHD controls. Number of errors (%) are given in Table 1 for each condition, separated for aphasics and RHD controls.

There were three conditions, each consisting of 20 trials with the condition marking outline cue furthermore subdivided into three conditions ($n = 6$ for marking most useful; $n = 6$ for marking least useful, and $n = 8$ for marking between most and least useful). In a first repeated measurement ANOVA (groups x conditions), only for the performances under the

Table 1. Number of errors (%) for each condition separated for aphasics and right hemisphere-damaged (RHD) controls

Conditions	Aphasics ($n = 60$)	RHD-controls ($n = 27$)
Marking outline cue (overall)	50.2	47.5
Pictorial cue	49.5	46.0
Dotted outline cue	49.0	46.0
Marking outline cue (separated)		
most useful	53.3	48.2
least useful	48.2	46.6
between most and least	48.5	46.2

Note: chance level = 87.5% errors

marking outline cue conditions, no significant effects were obtained ($F < 1$). Therefore in the subsequent two-way repeated measures ANOVA the items of the different marking outline conditions were collapsed, with groups as the between and conditions (no cue, pictorial, and marking outline cue) as the within subject factors. Again, the groups did not differ in overall error scores and no other comparisons or interactions approached significance ($F < 1$).

In order to determine whether aphasics and RHD patients, despite similar total error scores might have different error patterns according to the degree of deviation form the target stimuli, the same analyses were performed scoring only the very dissimilar distractor items as errors (3 and 4 mm deviations). These analyses did not reveal any further main effects or interactions. In aphasics none of the experimental conditions correlated significantly with any subtest of the Aachener Aphasie Test ($-0.04 \leq r \leq -0.18$).

Although all groups performed well above chance levels (87.5%) error rates were quite high (about 50% in all conditions). There seem to be several experimental variables which decisively influence the recognition of random shapes, namely exposure time and the similarity between alternatives on the multiple choice display (Bisiach and Faglioni 1974; Bisiach et al. 1975, 1979). Thus we designed a second experiment in which (1) exposure time was not 3 but 5 s and (2) only items that were clearly dissimilar were used for the recognition sheets. Since giving the different conditions randomly mixed might hamper patients from building up or following the processing strategy assumed by the cues, in the second experiment (3) items of the different conditions were not given randomly, but in blocks. Additionally, (4) LHD patients without aphasia were tested, and (5) only the no cue and the pictorial cue conditions were used.

Experiment II

Method

Material and Procedure. The stimuli to be recognized consisted of 24 complex random shapes constructed by Vanderplas and Garvin (1959a). Selected were 6 16-point shapes (numbers 1, 2, 3, 4, 5, 6) and 6 24-point shapes (numbers 2, 3, 6, 7, 9, 10) with a high association value (mean = 44.3), and 6 16-point shapes (numbers 25, 26, 27, 28, 29, 30), and 6 24-point shapes (numbers 22, 26, 27, 28, 29, 30) with a low association value (mean = 27.2). These sets of target stimuli included the shapes used by Bisiach and Faglioni (1974) and Bisiach et al. (1979).

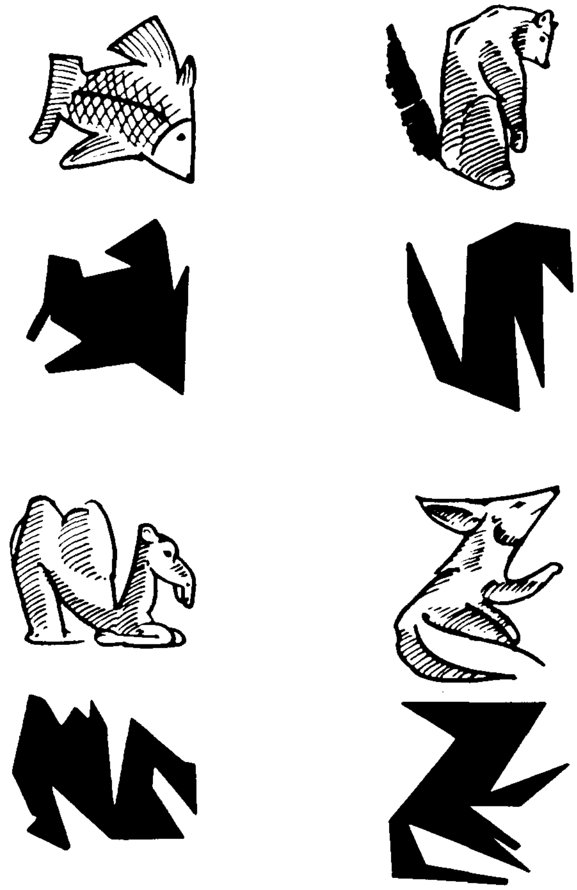

Fig. 2. Four examples of the stimuli used in the condition pictorial cue present

For each shape a corresponding picture was drawn showing an object, the contour of which closely resembled that of the shape to be remembered (see Fig. 2).

The stimuli ranged from 3 to 4 cm in size and were mounted on white cards, 7.5 × 10.5 cm in size.

Each subject was shown 12 shapes with a corresponding picture and 12 shapes with no such cue, one at a time. In the condition "pictorial cue present" (P+) an object drawing was placed on the table in front of the subject for 5 s. Then a card with a random shape was placed beside it and displayed for a further 5 s together with the object picture. In the instruction, including 6 examples, subjects were encouraged to relate the meaningful stimuli semantically to the random shapes by trying to "see the meaningful form in the meaningless one". In the condition "pictorial cue absent" (P−) an exclamation mark was displayed for 5 s, 5 cm high and mounted on a white card identical to those used for presenting the random shapes. It was followed by presentation of the random shape for a further 5 s.

Immediately following the presentation and removal of a target shape subjects had to identify the shape among 12 shapes of the same complexity and within a narrow range of association values. These shapes were mounted on sheets 10.5 × 29.9 cm in size, and arranged in two vertical rows. In order to increase the number of different alternatives in these recognition sheets 36 additional complex shapes (Vanderplas and Garvin 1959a) were used. For each target stimulus a different recognition sheet was constructed by sampling from the total pool of 24 target stimuli and the 36 nonpresented shapes. This sampling was done randomly with the restrictions that a stimulus which had been used as a target stimulus was not presented as a distractor until 12 other items had been administered and that the same distractor shape did not appear more than twice on successive recognition sheets.

An error was recorded when 1 of the 11 distractor shapes was selected instead of the shape just presented, or when no response was given within 60 s. Half of the subjects began with the P+ condition, followed by the P− condition (P+/P−). This order was reversed for the remaining subjects (P−/P+). Each mode of presentation consisted of equal numbers of shapes with 16 and 24 points and equal numbers of shapes with high and low association values.

Subjects. The subjects were 59 LHD patients with aphasia (43 male, 16 female), 18 LHD patients without aphasia (13 male, 5 female), and 20 RHD patients (15 male, 5 female) without aphasia. Classification of the aphasic subjects was based on the Aachener Aphasie Test (Huber et al. 1983). All patients were classified by this test as aphasic with an a posteriori probability of 100%. Nine patients were classified as amnesics, 19 as Broca's, 22 as Wernicke's, and 9 as global aphasics. The two nonaphasic groups had no indication of aphasia at any time in their clinical files. All patients had lesions restricted to one hemisphere according to clinical information, supported by EEG, neuroradiological, and CAT scan findings. All had been right handed according to the Oldfield (1971) scale, and all were native German speakers.

The three groups – each subdivided into subjects who received the P+ condition before the P− condition and those given the reverse order – were comparable with respect to age and duration of illness according to a two-way ANOVA (groups x order of conditions; $F<1.7$). This subdivision was included to assess any potential bias in the random assignment of the subjects to the different sequences of experimental conditions.

Groups were also comparable with respect to their educational and occupational status (χ^2 (4) = 0.81; $P>0.10$). They differed, however, with respect to etiology (χ^2 (4) = 12.3; $P<0.01$). While 84% of the aphasics had cerebrovascular etiology, 61% of the LHD nonaphasic patients and 55% of the RHD had a traumatic lesion.

Results

To stabilize variances, error scores were square-root transformed ($x = \sqrt{x} + \sqrt{x+1}$) before being submitted to ANOVA (Winer 1971). Mean numbers of recognition errors (square-root transformed) for shapes presented with and without a picture for the three groups subdivided according to the order of conditions are given in Table 2.

Since in previous ANOVAs no differences were found for the four subgroups of aphasics with respect to recognition errors and mode of presentation and the association value of the random shapes did not produce a significant main or interaction effect, only the results of a further three-way ANOVA will be reported here with groups (aphasics vs LHD without aphasia vs RHD) and order of conditions (P+/P− vs P−/P+) as between factors, and mode of presentation (P+ vs P−) as within factor. In this analysis a significant main effect was found for groups ($F(2,91) = 4.44$; $P<0.05$) and mode of presentation ($F(1,91) = 12.74$; $P<0.001$). A significant interaction between group x order of conditions also emerged ($F(1,91) = 2.69$; $P<0.05$). The most important interaction for our hypothesis, group x mode of presentation, just missed the conventional level of significance (F (1,91) = 2.69; $P=0.07$).

Table 2. Means of recognition errors (square-root transformed) for shapes presented without and with a pictorial cue for groups subdivided according to order of conditions

Order of conditions		Left hemisphere damaged (LHD)/ aphasics ($n=59$)	LHD ($n=18$)	RHD ($n=20$)
P−/P+	P−:	3.35	3.14	3.36
	P+:	2.76	2.60	2.92
P+/P−	P−:	4.27	3.28	2.21
	P+:	3.32	2.04	2.61

Although aphasics generally made more errors than RHD or LHD patients, according to post hoc *t*-tests the groups differed significantly only when the P+ condition was performed before the P− condition. For this order of conditions aphasics (mean = 3.8) performed significantly more poorly than RHD patients (mean = 2.4), but not any worse than LHD patients without aphasia (mean = 2.7). The significant main effect of mode of presentation refers to generally reduced error rates when shapes were presented together with a picture (mean = 2.9) compared to being presented without a cue (mean = 3.5). However, according to the interaction group x mode of presentation, the trend was for LHD patients with and without aphasia to gain more from the presence of a pictorial cue ($d=0.08$ and $d=0.09$) than the RHD patients ($d=$ 0.04); (see also Table 1). Introducing age and duration of illness as covariates in the ANOVA did not change these patterns of results.

In aphasics, given the P+ condition first, the number of errors in recognizing shapes without a picture but not those in recognizing shapes with a picture ($0.01 \leq r \leq -0.27$) correlated significantly with errors in the Token Test ($r=0.39$; $P<0.05$) and performance in the other subtests of the Aachener Aphasie Test ($-0.44 \leq r \leq 0.48$). For aphasics given the reverse order of conditions these correlations were not significant ($-0.27 \leq r \leq 0.27$).

Discussion

The results neither clearly support nor clearly disprove the findings and interpretation of Bisiach and Faglioni (1974) and Boller and De Renzi (1967) that LHD patients or aphasics are impaired in the recognition of random shapes due to an inability to attach meaning to such stimuli.

Obviously, in experiment I the tasks were too difficult. Under the assumpiton that to attach meaning takes a certain time, then the findings of Bisiach and coworkers (1979), that short exposure times result in impairment among RHD patients mean that exposure time in experiment I was possibly too short to relate the meaningful stimulus (object drawing) semantically to the random shape. Thus we designed a second experiment with a longer presentation rate of the items (5 s).

Although in this experiment LHD patients with aphasia showed the worst overall performance compared to the other subject groups, the three brain-damaged groups with a P−/P+ order did not differ from each other in their performance, while the groups with a P+/P− order did. Furthermore, the pictorial cue is generally advantageous for retention, but the postulated interaction group x mode of presentation was only of borderline significance.

With a P−/P+ order LHD patients showed not only a similar overall level of performance to RHD patients, but also nearly the same reduction of errors from the P− to the P+ condition (see Table 2). Considering these results, one may conclude either that all three groups profited from the help of a pictorial cue, or that no group profited from the cue, and that the increase in performance from P− to P+ was merely a practice effect. Certainly these results do not support the hypothesis that LHD patients with and without aphasia, in contrast to the RHD, have special difficulties in attaching meaning to meaningless shapes. However, the task was possibly now too easy so that none of the subjects found it necessary to make use of the pictorial cues when they were presented in the second half of the experiment.

The results of the groups with a P+/P− order of conditions were quite different, and the performance of the aphasics was significantly inferior to that of the RHD patients. In addition, the groups showed differences in performance across the P+ and P− conditions which corresponded exactly to the attach meaning hypothesis. Aphasics and LHD nonaphasics performed much better under the P+ condition than under the P− condition, while the RHD patients did not show a picture effect, or, if at all, performed better in the P− condition than the P+ condition. This, however, might again be due to a practice effect since the P− condition was presented after the P+ condition. For the aphasics given this order of conditions, the number of recognition errors for shapes presented alone correlated significantly with the performance of these patients in the Token Test and in the other subtests of the Aachener Aphasie Test. It seems implausible to attribute the difference between groups in this order of conditions primarily to a bias in the random assignment of subjects. All groups were comparable with respect to age and duration of illness. Introducing these variables as covariates in the ANOVA did not change the overall pattern of results.

Presupposing that the presentation of the representative, meaningful stimulus probably activates a verbal label referring to it (Paivio and Begg 1981) one may construe sequencing the experimental conditions such that a picture cue was given initially stimulated patients more than the reverse order to try to make use of a verbal encoding of the stimuli. Although instructed otherwise, these patients may not yet have clearly recognized that attributing a meaning to a shape might facilitate its later recognition and therefore they may not have tried primarily to use the pictorial cue as an aid in the retrieval and application of a conceptual category, instead they may have tried to apply and retrieve verbal labels to memorize the shapes when the cue was no longer provided. This could explain why aphasics given this order of conditions showed relatively poor overall performance and why evidently a relationship between the degree of language impairments and the recognition of random shapes presented without a picture existed only for these aphasics.

In addition, the mean numbers of errors in all groups were rather small, indicating that the task was apparently easy. This may be one reason why no more pronounced differences between the groups were obtained and why the pictorial cue was only of minor importance for the performance of the LHD patients. The relatively small number of errors might also explain why the association value of the shapes, assumed to indicate the resemblance of the meaningless stimuli to representative familiar figures (Vanderplas and Garvin 1959b), contrary to the findings of Bisiach and Faglioni (1974), had no differential influence on the recognition performance of the LHD patients.

Both experiments corroborate the view that not only the RH but also the LH is involved in the processing of complex visual material (e.g., Bisiach and Faglioni 1974; Boller and De Renzi 1967; De Renzi 1982; Sergent 1983). They offer, however, no clear-cut support for the assumption that LHD patients or especially aphasics are impaired in the recognition of complex random shapes because they fail to attach meaning or when trying to direct attention to certain parts of these stimuli.

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