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# Copying procedures in focal brain-damaged patients

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*We aimed to ascertain whether non-apraxic, focal brain-damaged patients used abnormal constructional procedures. We tested a series of consecutive patients, classified according to lesion locus and side against a matched sample of normal volunteers. Subjects had to copy the Rey-Osterreith Figure, a complex and structured item that explores copying strategies. We used special testing and scoring methods to analyze different steps of the copy. Unlike the controls, the patients did not choose the central elements of the figure as guiding structures. All patient groups followed an equivalent "pathological", "piecemeal" procedure.*

**Key Words:** Constructive abilities — brain lesion — neuropsychology.

## Introduction

Since Kleist [15] defined constructional apraxia, the effects of unilateral cerebral lesions upon visuo-spatial constructional abilities have been investigated thoroughly. Some authors have studied the frequency and severity of constructional apraxia in left and right brain-damaged patients, while others have focused upon the different basic impairments in the two groups [for reviews, see 5, 8]. According to one hypothesis [7], constructional disabilities can be attributed to an impairment of visuo-spatial perceptive functions in right brain-damaged patients and to a more general planning deficit or to an executive defect in left brain-damaged patients. Experimental investigations have failed to provide strong evidence in for this.

According to Gainotti [9] the dissociation between visuo-perceptive and planning disorders was clearly supported if expressed in terms of intra-hemispheric locus of lesion: a visuo-spatial impairment may underlie the constructional disabilities of parietal lobe patients, while a planning disability can subsume those of frontal lobe patients [17]. Pillon [21] tested this hypothesis by asking unifocal brain-damaged patients to copy drawings in two conditions: i) using spatial landmarks or ii) fragmenting the task in successive steps of increasing complexity. Pillon found a double dissociation between patients with posterior lesions, who were facilitated only by spatial landmarks, and anterior patients, who improved their copying by fragmenting the task. On the other hand, no difference was found between right and left brain damaged patients.

A different approach to constructional disturbances was designed to find out whether focal brain lesions could affect constructional strategies. This issue has been addressed directly by Semenza, Denes, D'Urso, Romani and Montorsi [26], who concluded that both right and left non-aphasic patients tended to use a global strategy, as well as normal subjects. On the other hand, aphasic patients used an analytic copying strategy and were forced to copy drawings piece-by-piece because

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of a planning defect. Binder [2] reported contrasting data: she asked patients to copy the Rey Complex Figure and adopted a special scoring procedure to identify the strategy adopted by subjects. She found that only normal subjects used a global approach. Both right and left patients broke the basic elements of the structure into fragments, suggesting that an intact right hemisphere does not ensure holistic visuo-spatial processing.

The above studies aimed to investigate copying strategies but they included also patients with severe constructional disabilities. For several reasons, the evaluation of overtly apraxic patients' drawings may be a confounding factor in the study of copying procedures per se. First, overt constructional disabilities may imply severe visuo-spatial or praxic impairments, or even general cognitive derangements. Second, it is very difficult to evaluate and score very distorted reproductions. Third, those studies explored drawing strategies only by means of indirect measures.

The present study was designed to investigate more strictly the effect of brain lesions upon copying strategies. In other terms, we tried to ascertain whether non-apraxic focal brain-damaged patients used abnormal constructional strategies. For this purpose we chose Rey-Osterreith Complex Figure, a complex and structured item for exploring copying strategies and adopted special testing and scoring procedures for analyzing different steps of the copying process.

## Patients and method

*Subjects*

We tested 95 consecutive right-handed unifocal brain-damaged in patients of the Fondazione Clinica del Lavoro, Campoli M.T. All patients had a stabilized lesion: mean time post-onset was 8.6 months (range 5-15). 45 patients had right-sided lesions (RBD, Right Brain-Damaged patients) and 50 left-sided lesions (LBD, Left Brain-Damaged patients). 26 LBD showed aphasic disturbances. In the majority of subjects (80%) unifocal lesions were demonstrated by CT scanning. The remaining patients could enter the experiment if they had only unilateral neurological signs but no previous strokes. All patients had vascular lesions, except 5 patients who presented focal lesions after surgery for benign intracerebral tumors. All patients completed the experimental battery, but only patients not affected by overt constructional disorders were included in the statistical evaluation. We excluded patients whose drawings did not allow identification of the elements of the original figure. But a patient who could copy the elements in the correct spatial relationships was included in the statistical analysis even if he omitted part of the figure. 16 of 45 RBD (35.5%) and 21 of 50 LBD (42%) have been excluded because their drawings were not recognisable. In the LBD group 10 out of 26 aphasic patients (38.4%) were excluded and 11 out 24 nonaphasic patients (45.8%). Exclusion percentages did not differ significantly either between RBD and LBD or between aphasic and nonaphasic LBD patients. Subjects who had had CT scans were also classified according to the intrahemispheric locus of lesion, irrespective of lesion side. We classified 30 patients as anterior, for their lesion involved frontal lobes, and 36 patients as posterior (10 patients were not classified because had only subcortical damage). 15 patients with posterior lesions (41%) and 9 patients with anterior lesions (30%) have been excluded because apraxic. The difference between anterior versus posterior exclusion percentages was not significant ($\chi^2 = .96$, d.f. 1, $p = .3$).

66 normal volunteers acted as control group. 6 of them were excluded (9%) from statistical analysis following the same criterion as for brain-damaged patients. Controls' exclusion percentage was significantly lower than that of brain-lesioned patients (39%) considered as a whole group ($\chi^2 = 18.2$, d.f. 2, $p = .0001$). Controls' age, male/female ratio, and education were matched with those of RBD and LBD, as showed in Table I.

*Method*

Our aim was to identify the strategy by which subjects drew and assembled single segments in a complex figure (Fig. 1).

Subjects were asked to copy the Rey-Osterreith figure [22]. The first copy was interrupted after

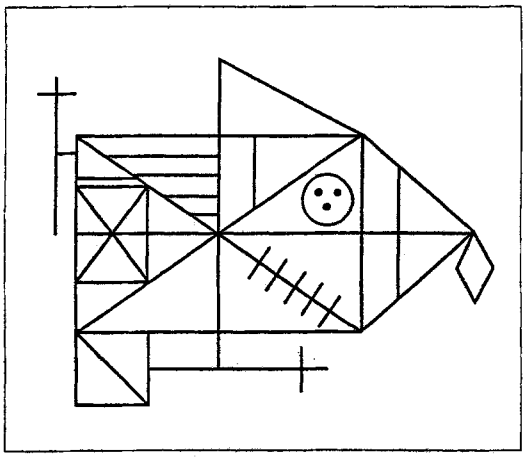

Fig. 1. *Rey-Osterreith Complex Figure.*

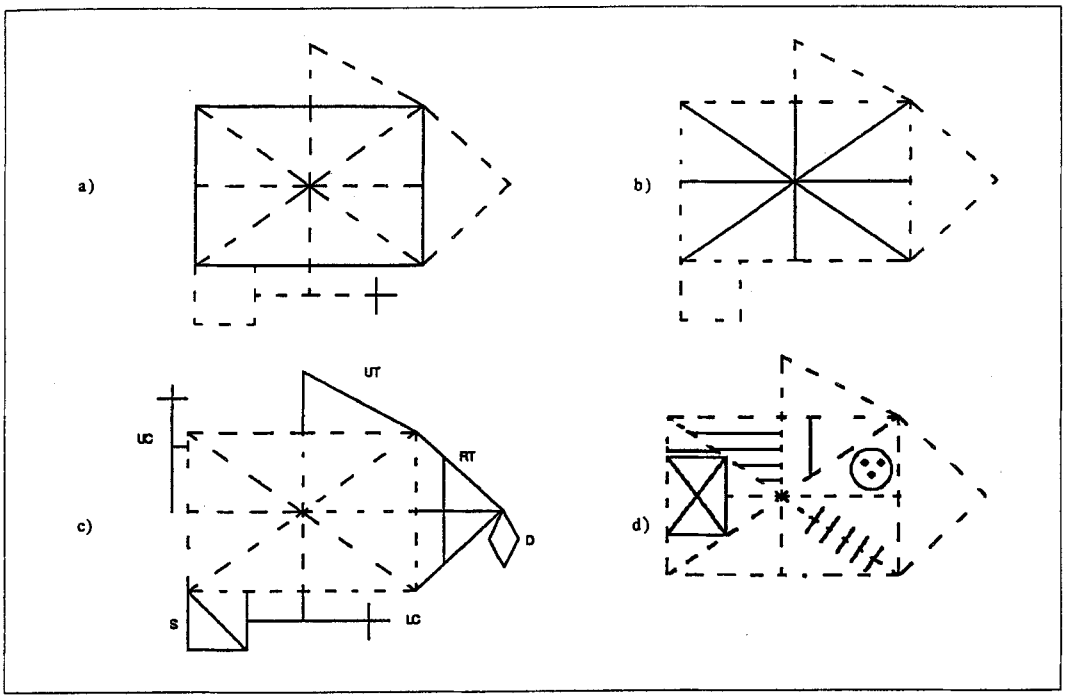


Fig. 2 *(a, b, c, d). The subunits of the Complex Figure: a) the Base Rectangle (BR); b) the Main Substructure (MS); c) the subunits of Outer Configuration (OC), that is divided into: Upper Cross (UC), Upper Triangle (UT), Right Triangle (RT), Diamond (D), Lower Cross (LC), Sauare (S); d) elements clustered as Inner Details (ID).*

they had drawn ten segments (about 25%) of the figure. They were then asked to draw a new copy, which was interrupted after twenty segments (about the half of the figure) and been drawn. Finally, a third, complete, copy was requested. This method seemed to us the simplest way to analyze successive stages of copy processes and to detect any modification of copying strategies in successive trials.

*Scoring procedure*

We did not use classical scoring methods [16, 23], because we focused our attention upon the order in which segments were drawn and assembled. We adopted a more analytical scoring method derived from that proposed by Waber and Holmes [28]. Our method considers the figure as composed of 44 segments plus the circle, and evaluates the reproduction of every single segment. For each unit a score of 2 is given for correct reproduction, and of 1 for partial reproduction, or wrong orientation (maximum score = 90).

Then, each element was categorized as belonging to one of four major components of the figure: Base Rectangle (BR, max score = 8; Fig. 2a), Main Substructure (MS, max score = 8; Fig. 2b), Outer Configuration (OC, max score = 40; Fig. 2c), Internal Details (ID, max score = 34; Fig. 2d). Further, since elements of Outer Configuration differ markedly in orientation and site, we broke down Outer Configuration into 6 components (see Fig. 2c): Upper Cross (UC, max score = 6), Upper Triangle (UT, max score = 4), Right Triangle (RT, max score = 8), Diamond (D, max score = 8), Lower Cross (LC, max score = 6), and Square (S, max score = 8).

Thus we had for each copy one Total Score, and 9 partial scores, referring to the 3 main components (BR, MS, ID) and to the 6 Outer Configuration subcomponents (UC, UT, RT, D, LC, S). Since partial scores, and total scores of the three copies differed markedly one from another, all results will be expressed, and treated, as percent scores.

We then calculated a Consistency Index to find out whether copying procedures were consistent within subjects, or whether subjects improved with practice. The examiner assigned a score of 1 to the subject who drew another copy beginning from the same subunit as in the first one, and a score of 2 if both subsequent copies were started as the first one. The score was zero if the patient changed the starting subunit each time.

TABLE I. *Demographic data for controls and patients, classified according to both lesion side and lesion locus. Number of subjects (N), male/female ratios, mean age and mean education (in years), with Standard Deviations (SD), are reported.*

| | N. | M/F ratio | Age (yrs) Mean | Age (yrs) SD | Education (yrs.) Mean | Education (yrs.) SD |
|---|---|---|---|---|---|---|
| Controls | 60 | 2.5 | 58.8 | 7.6 | 7.6 | 5.1 |
| *Lesion side* | | | | | | |
| RBD | 29 | 1.6 | 64.1 | 11.3 | 4.6 | 2.8 |
| LBD | 29 | 2.2 | 59.4 | 11.8 | 6.4 | 3.5 |
| (Aphasics) | 16 | 2.9 | 56.5 | 12.1 | 6.4 | 4.5 |
| *Lesion locus* | | | | | | |
| Anterior | 21 | 1.8 | 57.4 | 12.7 | 5.6 | 2.4 |
| Posterior | 21 | 2.4 | 62.4 | 10.1 | 6.8 | 4.2 |

TABLE II. *Mean Total Scores (as percentages) at the three copies and mean Consistency Index, with Standard Deviations (SD), are reported for controls and patients.*

| | First Copy | | Second Copy | | Final Copy | | Consistency Index | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| Controls | 25 | 5 | 44 | 12 | 82 | 18 | 1.7 | .46 |
| *Lesion side* | | | | | | | | |
| RBD | 22 | 5 | 34 | 8 | 60 | 19 | 1.6 | .56 |
| LBD | 20 | 7 | 34 | 10 | 62 | 22 | 1.6 | .61 |
| (Aphasics) | 22 | 5 | 35 | 9 | 61 | 23 | 1.6 | .58 |
| *Lesion locus* | | | | | | | | |
| Anterior | 22 | 6 | 33 | 9 | 63 | 23 | 1.8 | .44 |
| Posterior | 21 | 6 | 35 | 10 | 60 | 22 | 1.7 | .58 |

Evaluation of copies, exclusion of apraxic patients, and scoring were performed by two examiners independently. Inter-rater reliability score was 0.95 for the exclusion of apraxic patients and 0.90 for the score assignment.

## Results

Brain-damaged patients scored lower than normal controls on all three copies, even though we had excluded patients with overt constructional difficulties.

Following the classification by lesion side, we found marked differences between controls and patients, but only small differences between LBD and RBD on all three Total Scores (Table II).

Controls' partial scores were not uniformly higher than those of patients (Table III). A differential pattern of copying procedures appeared, made stronger by the high degree of consistency through the three copies: patients and controls achieved more than 80% of maximum score on the Consistency Index, without significant differences between the groups, $F(2,103) = .26$.

To ascertain whether left and right brain-damaged patients used the same copying strategy as normal subjects, we did a separate two-way analysis of variance for each of the three copies, with groups (controls, RBD and LBD) and subunits as independent factors. The group effect was not significant at the first copy [$F(2) = 2.9$, $p = .09$], but it became significant at the second and third copies, $F(2) = 12.4$, $p = .0001$ and $F(2) = 74.7$, $p = .0001$. This is explained by the fact that the small number of elements of the first copy flattened the differences between groups. The subunit factor was significant throughout the three copies [$F(8) = 25.8$, 26.2, and 13.7 respectively, $p = .0001$], thus showing that subunits were not equivalent for the three groups. The most interesting finding was that the group-subunit interaction was highly significant for the first and second copies [$F(16) = 4.2$ and 2.8 respectively, $p = .0001$), while it was weakly significant at the final copy [$F(16) = 1.7$, $p = .04$). Before performing more detailed statistical analysis, we wanted to ascertain whether the presence of aphasic disturbances could affect copying procedures. A two-way analysis of variance contrasted aphasic patients' scores with those of nonaphasic LBD in a way similar to the previous one. At all three copies the group effect was far from significance level, $F(1) = .3$, 2.2, and 3.1 respectively, as was the group-subunit interaction, $F(8) = .5$, 1.1, and .3 respectively. This finding suggested that aphas-

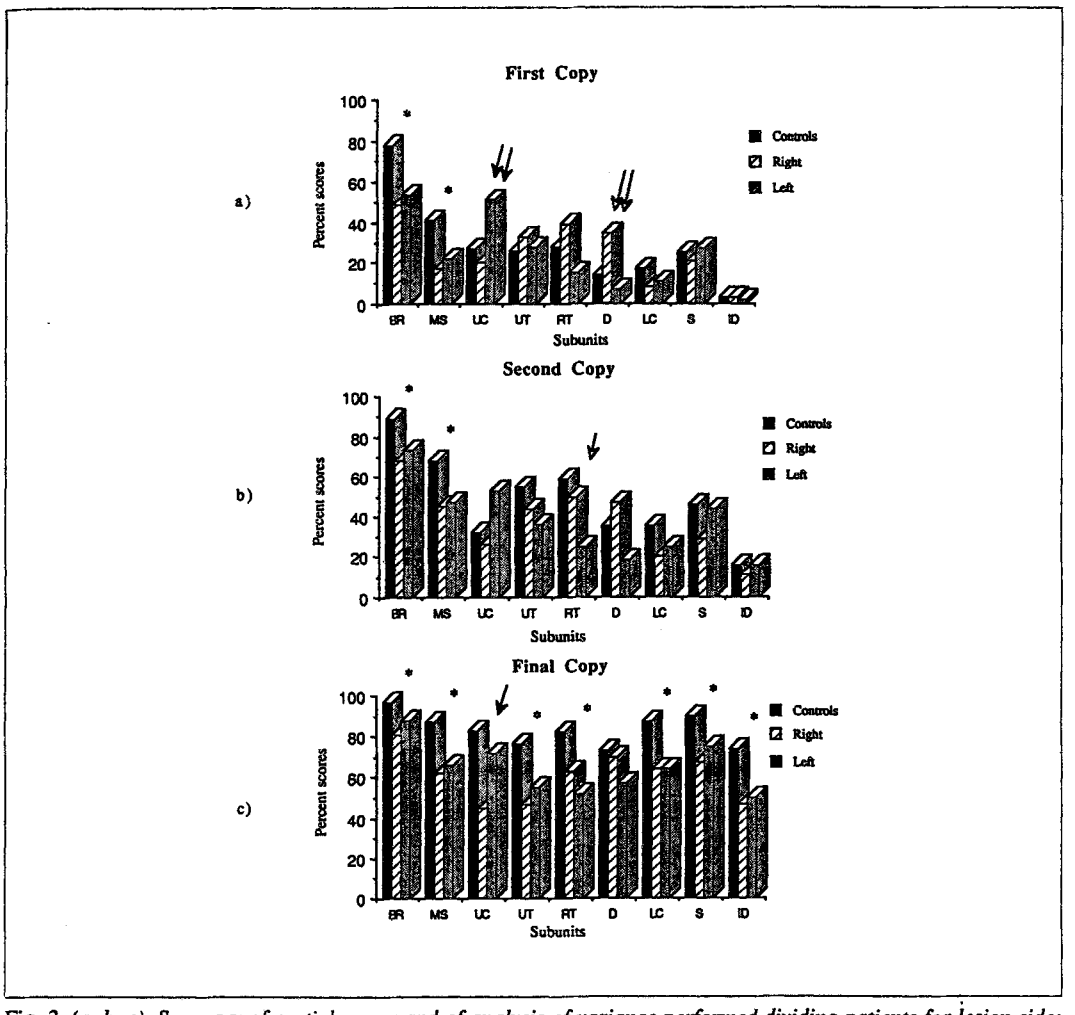


Fig. 3 *(a, b, c). Summary of partial scores and of analysis of variance performed dividing patients for lesion side: the asterisk means a significant superiority of controls over both patient groups; the double filled arrow means a significant superiority of LBD over the other two groups; a single filled arrow means a significant superiority of LBD over RBD; a double blank arrow means a significant superiority of RBD over the two other groups; a single blank arrow means a significant superiority of RBD over LBD.*

ic disturbances did not affect this task. Consequently, aphasic and nonaphasic LBD were considered in the same group.

For the successive statistical analysis we adopted conservative significance levels because of the large number of comparisons: .01 both for one-way analysis of variance applied to each subunit, and for post-hoc comparisons on Scheffe' tests.

The analysis is summarized in Fig. 3. At the first copy (Fig. 3a), BR and MS scores revealed a significant group effect [$F(2,115)=14.9$, $p=.001$ and $F(2,115)=9.1$, $p=.002$ respectively], the controls performing significantly better than both patient groups. Interestingly, LBD patients were significantly better than the other two groups at reproducing UC, the leftmost subunit [$F(2,115)=5.1$, $p=.007$], where controls and RBD did not differ from each other. The opposite findings were obtained on reproduction of D (the right-most subunit), where RBD did significantly better than the other two groups (controls and LBD), which did not differ from each other, $F(2,115)=7.34$, $p=.001$. For the remaining five subunits the group effect was not significant. It is worth remembering that these differences among groups at an early stage of copy were responsible for group-subunit interaction in the two-way analysis, where the general group effect was not significant. In

TABLE III. *Mean Partial Scores (±Standard Deviations) at the three copies are reported (as percentages) for controls and patients.*

| | Controls | Lesion Side | | Lesion Locus | |
|---|---|---|---|---|---|
| | | RBD | LBD | Anterior | Posterior |
| *First Copy* | | | | | |
| BR | 78±29 | 49±25 | 54±24 | 51±27 | 54±24 |
| MS | 60±41 | 17±18 | 22±18 | 23±18 | 16±20 |
| UC | 24±41 | 20±31 | 51±42 | 45±44 | 29±39 |
| UT | 26±40 | 33±41 | 28±38 | 36±44 | 27±37 |
| RT | 28±37 | 39±34 | 15±27 | 27±37 | 27±31 |
| D | 14±29 | 35±38 | 7±22 | 29±43 | 14±23 |
| LC | 17±28 | 8±21 | 11±28 | 5±16 | 16±32 |
| S | 25±41 | 21±37 | 27±32 | 20±30 | 29±34 |
| ID | 3±8 | 3±9 | 2±3 | 1±4 | 1±2 |
| *Second Copy* | | | | | |
| BR | 89±20 | 68±27 | 73±24 | 68±28 | 69±24 |
| MS | 68±27 | 45±24 | 47±25 | 51±24 | 43±26 |
| UC | 32±45 | 26±34 | 53±43 | 46±42 | 41±44 |
| UT | 55±44 | 44±39 | 36±36 | 45±38 | 32±37 |
| RT | 59±39 | 50±28 | 25±36 | 39±32 | 39±33 |
| D | 35±42 | 47±37 | 18±32 | 30±39 | 30±34 |
| LC | 35±40 | 20±28 | 25±37 | 20±29 | 27±42 |
| S | 46±47 | 29±38 | 44±40 | 28±40 | 43±40 |
| ID | 16±15 | 11±12 | 16±17 | 14±14 | 17±17 |
| *Final Copy* | | | | | |
| BR | 97±8 | 81±18 | 88±13 | 85±17 | 83±16 |
| MS | 87±18 | 62±24 | 66±25 | 68±25 | 61±23 |
| UC | 83±30 | 45±40 | 72±27 | 60±38 | 57±37 |
| UT | 76±37 | 47±38 | 55±37 | 64±32 | 51±40 |
| RT | 82±26 | 63±26 | 52±32 | 57±30 | 57±32 |
| D | 73±33 | 70±26 | 57±41 | 66±38 | 61±34 |
| LC | 87±19 | 64±28 | 64±28 | 70±30 | 62±32 |
| S | 90±18 | 67±35 | 75±23 | 70±30 | 72±39 |
| ID | 74±22 | 47±21 | 50±28 | 49±28 | 50±26 |

other words, these data show that at this stage the three groups did not differ in overall accuracy of picture reproduction, but specifically differed in copying procedures.

Also at the second copy (Fig. 3b), BR and MS were reproduced significantly better by controls, $F(2,115) = 10.8$ and 11.1 respectively, $p = .0001$), without any difference between the two patient groups. However, for the two extreme subunits, the tendency of brain-lesioned patients to reproduce first and better the subunit ipsilateral to the lesion did not reach our significance level either for UC [$F(2,115) = 3.4$, $p = .03$), or for D [$F(2,115) = 4.37$, $p = .015$). However, another right subunit, RT, showed a significant group effect, with LBD patients scoring lower than the other groups (controls and RBD), $F(2,115) = 8.8$, $p = .001$.

At the third copy (Fig. 3c), data showed a generalized, significant superiority of controls over the two patient groups, which did not differ from each other. This was true for BR [$F(2,115) = 17.4$], MS [$F(2,115) = 16.9$], UT [$F(2,115) = 7$], RT [$F(2,115) = 12.2$], LC [$F(2,115) = 13$], S [$F(2,115) = 9.5$], and ID [$F(2,115) = 18$] ($p = .0001$ for all of them). The only two exceptions were for the rightmost and the leftmost subunits: LBD patients achieved the worst scores in reproducing D, but the group effect was not significant, $F(2,115) = 2.3$. For UC the group effect was significant, $F(2,115) = 13.5$, $p = .0001$, but here RBD obtained the worst scores. The differential data at the two extreme subunits were responsible for the weak group-subunit interaction at the final copy, where the main finding was the superiority of control group over brain-lesioned patients. Examining only this final stage of reproduction, as is usually done, any observation about copying procedures would be impossible: One could only underline the significance disadvantage of RBD in reproducing leftsided elements.

The same analysis was repeated when patients were classified according to intrahemispheric lesion locus, irrespective of lesion side. Here, too, controls fared better than patients with small differences between the two patient groups (Table II). No difference was found in the Consistency Index, $F(2,87) = .2$. Two-way analysis of variance,

with groups (controls, anterior, and posterior brain-lesioned patients) and subunits as independent factors, was performed for each copy. Once again, the group effect was not significant at the first copy, $F(2) = 1.5$, but it became significant at the second, $F(2) = 10.6$, $p = .0001$, and at the third copy, $F(2) = 56.5$, $p = .0001$. This finding confirmed that our testing procedure isolated an early stage of the copying process where differences among groups were not influenced by overall accuracy in reproducing subunits. The subunit factor was significant throughout the three copies, thus confirming that subunits were not equivalent in the copying process, $F(8) = 19.5$, 17.7, and 9.3, $p = .0001$ respectively. This time, the group-subunit interaction was clearly significant only for the first copy, $F(16) = 2.4$, $p = .001$, while it approached significance for the second copy, $F(16) = 1.7$, $p = .05$, and was not significant at the final copy, $F(16) = .6$. So, two-way analysis results were quite similar to the previous ones, but interactions were weaker. In fact, the two patient groups scored quite similarly (Table III).

Further statistical analysis followed the same method as for lesion side, with the same significance constraints. Results are summarized in Fig. 4. At the first copy (Fig. 4a), once again controls were the best group in reproducing the main elements of the figure, namely BR and MS [$F(2,99) = 10.5$, $p = .0001$ and $F(2,99) = 7$,

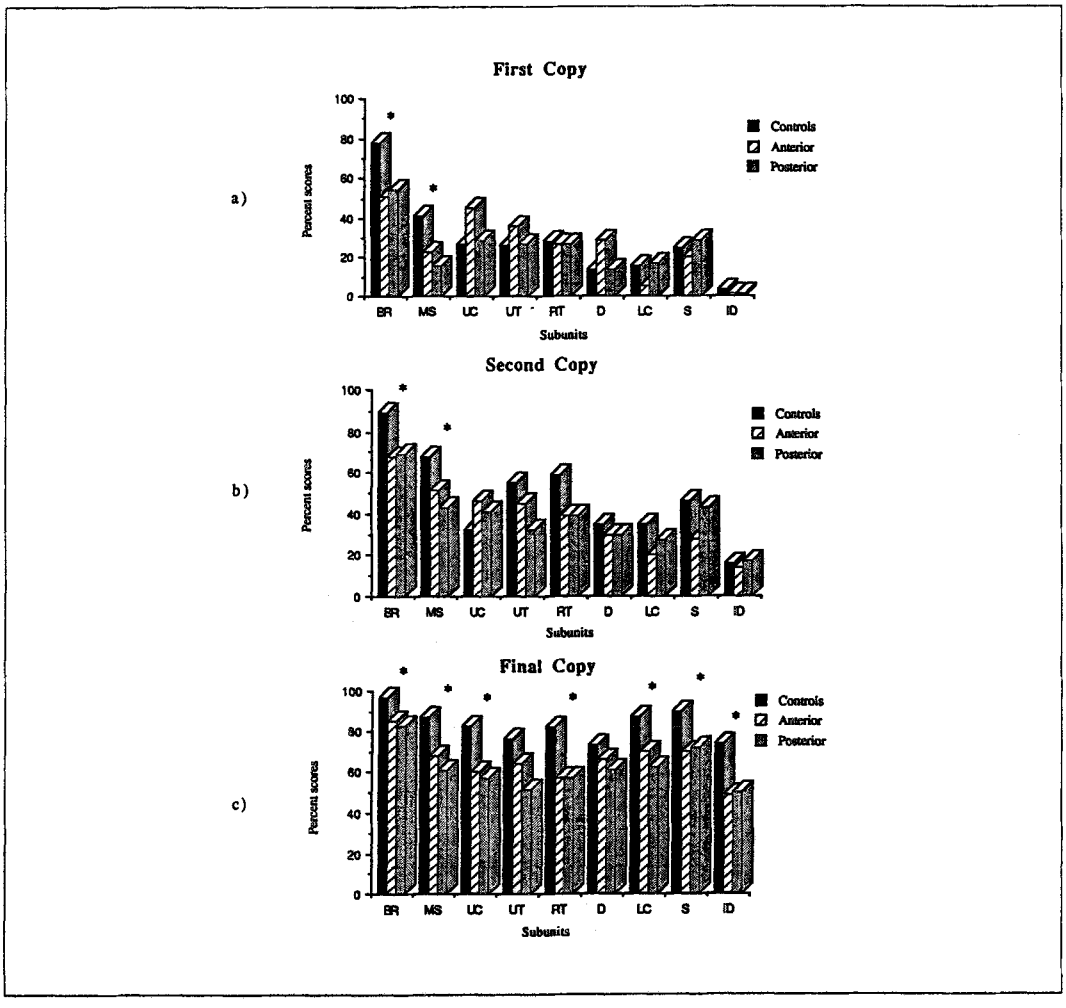


Fig. 4 *(a, b, c). Summary of partial scores and of analysis of variance performed dividing patients for lesion locus: the asterisk means a significant superiority of controls over both patient groups.*

p = .001) respectively], with anterior and posterior patients being similar to each other. For the remaining subunits the group effect was not significant. It must be noted that the two patient groups did not differ from each other for any subunit else. At the second copy (Fig. 4b), a clear superiority of controls was found both for BR and MS over patients, $F(2,99) = 10.4$, $p = .0001$, and $F(2,99) = 8.7$, $p = .0003$ respectively. Finally, at the third copy (Fig. 4c), a generalized, significant superiority of controls was evident for all subunits but two: BR [$F(2,99) = 14.6$], MS [$F(2,99) = 15.1$], UC [$F(2,99) = 6.7$], RT [$F(2,99) = 9.5$], LC [$F(2,99) = 9.9$], S [$F(2,99) = 8$], and ID [$F(2,99) = 13$] ($p = .0001$ for all of them). The only two exceptions were for UT, where group effect only approached our significance criterion [$F(2,99) = 3.9$, $p = .02$], and for D [$F(2,99) = 1$]. No difference was found between the two patient groups on Scheffe's tests.

*Summary of results*

Analysis of variance results evidenced that when patients were classified according lesion side, controls achieved a significantly better score in the reproduction of BR and MS in the two early stages of the copy, while each patient group performed better than the other, and also better than controls, in reproducing the subunit ipsilateral to its lesion side. At the final copy these differences disappeared, because controls showed generalized better scores. The only exception to these findings was the significantly lower score of RBD in the reproduction of the leftmost subunit (UC).

The classification based upon lesion site, irrespective of lesion side, failed to detect differences between patient groups. Analysis of variance could only support the finding that normal subjects tended to reproduce first and best the two central, main subunits (BR and MS), while brain-lesioned patients did not. Controls' generalized superiority was confirmed at the third copy, where group-subunit interaction was not significant.

## Discussion

The aim of this paper was to ascertain whether focal brain lesions could induce changes in copying procedures independent of overt disturbances of constructional abilities. We used a complex, structured item and an analytical scoring method which could allow the detailed observation of copying procedures. A first, marginal result of our study was that within a sample of consecutive brain-lesioned patients we had to exclude from statistical evaluation, because of constructional deficits, a similar number of right and left brain-damaged patients. Our data argue against a discrepancy in the frequency of constructional disabilities between LBD and RBD, or between aphasic and nonaphasic LBD. The overall percentage of brain-lesioned patients with constructional disabilities (39%) was fairly high if compared to other studies [8], but this finding is likely due to the relative complexity of the task used.

The major focus of our study was copying procedures. We adopted a testing method which arbitrarily isolated two intermediate stages of the copy plus the final production. In particular, we identified a first stage in which overall accuracy was similar in all groups, while subjects differed only in partial scores, i.e. in copying strategies. As for the second and the final copy, both LBD and RBD were quantitatively inferior to normal subjects. They differed from each other and from controls in partial scores. Data seem to suggest that both groups of patients adopted a piece-by-piece copying strategy, both beginning from elements of Outer Configuration homolateral to their lesion side. Actually, in the first two copies, LBD were best at reproducing the leftmost component (UC), while RBD were best at reproducing the rightmost one (D). Both groups, indeed, obtained significantly lower scores in reproduction of the two main components (BR and MS), which appear to be the most important elements in controls' early stages of the copy. By contrast, the distinction between patients whose brain lesion involved the frontal lobes, defined as anterior, and patients with posterior lesions did not evidence any difference between the two groups. However, also this part of the statistical analysis gave support to the idea that patients followed a different copying process, because they did not reproduce first and best the main subunits of the figure. These considerations do not imply, however, that patients performed a line-by-line copy, as do visual agnosic patients, who do not recognize figural entities [29]. Instead, data suggest that focal patients tended to copy the picture piece-by-piece, reproducing basic geometric units, without any consideration of their respective relevance in the figure. The divergences among groups cannot be explained by the different use of preferred hand in copying (RBD could copy with the right, preferred hand, while not all LBD could do it): actually, it has been argued that this factor, while being able to affect accuracy, does not influence the choice of copying procedures [26].

Controls' results are consistent with other studies showing that normal subjects plan their drawing, beginning it from the more salient organizational unit, the Base Rectangle [2]. Developmental data, too, suggest that Base Rectangle and Main Substructure become the guiding structures of normal copy as age increases over 13, when children abandon the "figural" approach according to which

they start the copy from a top left anchor point [20, 28]. A common interpretation of developmental data is that at about age 13 children begin to acquire formal operational thinking, and begin to treat copying as a logical problem too [28].

As for patients' data, our study is not easily comparable with previous ones, because we selected patients without overt constructional disabilities. However, our results are very similar to those reported by Binder [2], who did not find any difference between RBD and LBD, with the same kind of material.

Our results are also in agreement with the classic study by Warrington, James and Kinsbourne [30], who claimed that left and right brain-damaged patients, even though matched for drawing disability, had a different functional impairment: LBD showed more difficulties in planning the drawing and in processing details of stimuli, while RBD were impaired in using appropriate visuo-spatial parameters. At first glance, Warrington et al.'s conclusions seem different from ours. However, these authors identified one group of RBD and one of LBD with mild drawing disabilities, whose performances did not show any difference from each other. "Negative" groups' results were similar to our patient results, so that our study is at least partially consistent with that paper (the authors did not compare "negative" patients' results with those of normal subjects, since they focused on apraxics' functional impairment).

Present findings suggest that both groups of LBD and RBD with (at worst) slight constructional disturbances fail similarly in organizing copying process as normal subjects do. This may be considered a basic impairment, while other or more severe deficits would be necessary for determining constructional disabilities in overtly apraxic patients. The interpretation of our findings is not straightforward: our data suggest that patient groups basically followed an equivalent procedure and do not support the view that brain hemispheres differ from each other in general cognitive styles. Some authors have proposed that the right hemisphere is mainly concerned with visuospatial processes, while the left is more involved in planning activities [18, 30]. If this were the case, we should have expected RBD to show a significant effect of figural properties of the subunits, as we did in some respects (the different score for right and left elements).

However, we should also have found simplified copies with missing details in LBD, but we did not. Furthermore, also LBD (as RBD) were affected by figural properties, and their Consistency Index did not differ from that of RBD and controls, thus denying that LBD can improve their performance by practice, as predicted by the hypotheses of planning disorder [30]. Consequently our study, as well as others [10, 21], does not support the theory. To accommodate our findings within this theoretical framework we should have to admit that different impairments in LBD and RBD could lead to equivalent copying procedures. This interpretation, however, would seem an *ad hoc* adjustment of the theory and probably would lack explanatory value. The same argument holds good when the planning/visuoperceptual dichotomy is based upon a different intrahemispheric locus of lesion.

Another popular dichotomy is that between holistic versus analytic cognitive style considered typical of right and left hemispheres, respectively [4]. In some studies this global/local dichotomy is not properly distinct from the previous one, because sometimes a global approach to copying has been correlated with good planning abilities. For example, aphasic patients have been reported to follow an analytical copying strategy, interpreted as due to a planning disorder [26] (they could have been expected to show a trend toward "global", less detailed, productions on the basis of their left brain lesion). Anyway, also according to this point of view, one would have expected to find different procedures in LBD and RBD. In particular, one would have expected a great discrepancy between the two groups in reproducing the basic subinits (BR and MS), with higher scores in LBD for their putative tendency to reproduce the stimulus globally. Consequently, our data argue against this hypothesis, even though it remains possible that stimuli with more differentiated local versus global features could evidence such a dichotomy, particularly in perceptual processes [6, 24].

In summary, our data show that patient do not choose central elements of the figure as guiding structures and suggest that all patient groups followed a "pathological" procedure. This finding could be interpreted in two ways. According to the former interpretation, patients suffered from a reduction of planning abilities and could not organize copying processes as normals do. In other words, non-apraxic brain-lesioned subjects would show a reduction of "logical" abilities. In this case, cerebral lesions would have the non-specific effect of inducing patients to rely on simple "analytical" strategies: LBD would begin to copy from a top left anchor point as normal children do [28], and RBD would be forced to start from the rightmost element, because of their attentional defect, still evident in the final copy (worst score in UC reproduction). Even though our study was not easily comparable to others, it is worth mentioning that a "logical" impairment in constructional abilities, resulting in "piecemeal" reproductions, has still been argued in LBD [2] and also in aphasic patients [26]. Recently, it has been sug-

gested that also RBD's constructional disturbances can be correlated to impaired reasoning abilities [1]. However, opposite findings have been reported (for example: [11]), and, on the other hand, such a hypothesis offers some problems of theoretical interpretation. Actually, some authors have postulated the existence of a central-processor for hierarchically structured material [14], but it would be difficult to argue for this kind of deficit in all brain-lesioned patients.

Otherwise, one would have to admit a general, non-specific reduction of cognitive resources due to the brain-damage, even without suggesting something like a "mass-action" of the lesion. In fact, while the effect of lesion size has been denied in copying disabilities [3], it is arguable that brain-damaged patients prefer to rely upon simple strategies when coping with new problems. However, this conclusion would not be warranted on the basis of present evidence alone.

The latter, alternative, hypothesis about the failure to organize copying procedures would predict that patients are forced to this behaviour by a major attentional bias.

Actually, differences between groups appeared when subjects were classified by lesion side, while they disappeared with the anterior/posterior distinction, as if a main factor had been casually spliced in the two new groups. According to this hypothesis, subjects would preferentially process objects ipsilateral to their lesion and consequently would not build a unitary, global representation of the stimulus to be copied. This interpretation would agree with studies showing opposite exploratory strategies in LBD and RBD [31].

Further, independent evidence would be necessary to support either theoretical conclusion. From an empirical point of view, our results underline that a complex interaction of mental phenomena contributes to actual patients' constructional productions. We have analyzed copying processes through the isolation of two arbitrarily chosen, intermediate stages, and we have found some changes in copying procedures of non-apraxic patients. The "piecemeal" approach to the copying of geometric drawings could be considered the result of a basic adaptation of patients to the task. Further functional impairments, such as perceptual attribute processing defects [12], visuo-spatial coding defects, mental deterioration and so on, would be necessary to determine overt constructional disabilities.

Our study represents a step toward a different approach to constructional abilities, one that relies on the observation of procedures and of mental processes whereby a subject produces a copy. In this perspective, the conventional right/left or anterior/posterior dichotomies are unsatisfactory, also in view of recent studies showing the interaction of both hemispheres in simple visuospatial processes [19].

More detailed theoretical frameworks, like the newly developed cognitive models [13, 25, 27], and different clinical approaches are probably needed before we can comprehend constructional abilities more clearly.

**Sommario**

*Ci siamo posti lo scopo di verificare se pazienti cerebrolesi focali non aprassici mostrassero procedure anomale di copia.*

*Abbiamo studiato una serie consecutiva di pazienti, classificati secondo il lato e la sede della lesione, ed un parallelo gruppo di volontari normali. I soggetti dovevano copiare la Figura di Rey-Osterreith, un materiale complesso che permetteva di esplorare le strategie di copia. Abbiamo adottato procedure di somministrazione e di valutazione per analizzare le diverse tappe della copia.*

*A differenza dei controlli, i pazienti non sceglievano la struttura centrale come elemento guida della copia. Tutti i gruppi di pazienti seguivano una analoga procedura "patologica".*

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