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Relationships between Constructional and Visuospatial Abilities in Normal Subjects and in Focal Brain-damaged Patients

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ABSTRACT

We tested 125 normal subjects and 24 right and 22 left focal brain-damaged patients (RBD and LBD) on the Rey figure copying test and on a battery of perceptual and representational visuospatial tasks, in search of relationships between constructional and visuospatial abilities. Selected RBD and LBD were not affected by severe aphasia, unilateral spatial neglect or general intellectual defects. Both RBD and LBD showed defective performances on the constructional task with respect to normal subjects. As regards visuospatial tasks, both patient groups scored lower than normal subjects in judging angle width and mentally assembling abstract geometrical figures; moreover, RBD, but not LBD, achieved scores significantly lower than healthy controls in judging line orientation and analyzing geometrical abstract figures. Post-hoc comparisons did not reveal any significant differences between RBD and LBD. Multiple regression analysis showed that visuospatial abilities correlate with accuracy in copying geometrical drawings in normal subjects and in RBD, but not in LBD. From a theoretical perspective, these findings support the idea that visual perceptual and representational abilities do play a role in constructional skills.

Visuospatial perception is a term which refers to the analysis of spatial relationships of objects among each other and with the observer (De Renzi, 1982). This label is quite loose and may embrace elementary (e.g., location of points in the space, appreciation of dimensions, orientation or distance of an object) and complex (e.g., recognition of shapes, maze learning, mental rotation) processing abilities. For this reason, De Renzi (1982) suggested the term spatial perception in reference to elementary processing stages, while he used the term spatial cognition to designate more complex mental abilities requiring the use of mental (“internal”) representations. Throughout the present article we will follow this operational distinction between perceptual and representational abilities to refer to simple and complex aspects of visuospatial skills. Moreover, we will use the terms constructional apraxia and constructional disturbances, for designating any drawing impairment, irrespective of the kind of errors and of putative underlying visuoperceptual, motor or programming disturbances (Gainotti, 1985).

Since early studies, a link between visuospatial disorders and constructional apraxia has been hypothesized, at least to explain constructional disturbances in right focal brain-damaged patients

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(for reviews, see Gainotti, 1985, and Grossi & Trojano, 2001). However, a few modern studies have tried to verify this hypothesis in group studies. Mack and Levine (1981) reported that constructional abilities, measured by means of a nonexecutive task, were correlated with line length ($r = .84$) and angle size discrimination ($r = .56$) in right brain damaged patients (RBD), while left brain damaged patients (LBD) performed better than right lesioned patients on constructional and visual discrimination tasks and did not show such a correlation ($r = .37$, and $r = .06$, respectively).

Kirk and Kertesz (1989) observed that drawing disabilities correlated strongly with performance on a visuoperceptual task ($r = .77$) in patients with right hemisphere lesions whilst correlating more strongly with verbal comprehension subtests of the Western Aphasia battery (Kertesz, 1982) and with severity of hemiparesis (scored on a 0–4 scale, on the basis of a clinical assessment) in the left hemisphere group. Kirk and Kertesz concluded that constructional disorders can originate from a visuoperceptual deficit other than hemineglect in right brain damaged patients whilst it could be linked to disorders at the semantic or elementary motor level in patients with left-sided lesions. However, it should be highlighted that since Kirk and Kertesz employed a free-drawing task in their study, their conclusions may not be replicated with a copying task. Furthermore, the visuospatial deficit in right lesioned patients was identified using Raven's Progressive Matrices (Raven, 1982), which tap not only perceptual skills but also general intellectual abilities (Lezak, 1995).

More recently, Carlesimo, Fadda and Caltagirone (1993) assessed constructional abilities by the copying of geometric figures in RBD and LBD and used judgement of line orientation, comparison of distorted geometric figures, a 'tapping' test (elementary motor skills) and a 'tracking' test (spatially guided motor skills) to explore the various subskills possibly involved in the process of construction. To complete the battery, Raven's Progressive Matrices were incorporated as a measure of intellectual abilities. Carlesimo et al. observed that drawing abilities significantly correlated with tracking performance ($r = .54$) in right brain damaged patients, and with scores on the tapping test ($r = .40$) in left hemisphere patients. The authors concluded that the basic disturbance in right hemisphere apraxics is more likely to be an alteration in their ability to carry out spatial manipulations than a visuospatial deficit per se (in this group, judgement of line orientation correlated only marginally with drawing performance: $r = .31$) whilst in left hemisphere patients, a disorder at the elementary motor level could play a more crucial role.

Therefore, several inconsistencies are present in literature, while the most recent study on this issue (Carlesimo et al., 1993) would show that performances on perceptual simple (line orientation task) or complex (identification of abstract geometric figures) visuospatial tasks would not significantly contribute to drawing. However, recent theoretical contributions would indeed suggest that visuospatial abilities are involved in constructional tasks (Grossi & Trojano, 2001; Guérin, Ska, & Belleville, 1999). Moreover, the detailed assessment of visuoperceptual and representational abilities is enclosed in virtually all studies on single patients affected by constructional disturbances (e.g. Papagno, 2002; Suzuki, et al., 2003; Trojano & Grossi, 1998), based on the assumption that the link between visuospatial and constructional skills does exist.

The problem then arises to explain why research on groups of focal brain damaged patients has yielded inconsistent results. The first potential source of result variability refers to the influence that other cognitive disturbances, such as general intellectual deterioration, aphasia or spatial hemineglect, can exert on drawing performances (Gainotti, 1985), thus obscuring any possible visuospatial-constructional relationships. The second methodological issue refers to the lack of homogeneous operative definitions of visuospatial and constructional skills, and consequently of homogeneous assessment procedures used in different studies (Grossi & Trojano, 2001). In particular, as regards visuospatial abilities, one or two visual "perceptual" (as defined above) tasks have been used in different research studies, but without a clear rationale for choosing them: for example, Carlesimo et al. (1993) employed the classic line orientation test (Benton, Hannay & Varney, 1975), while other authors assessed line length and angle size discrimination (Mack & Levine, 1981), or localization of point positions (De Renzi & Faglioni, 1967). Moreover, only a few studies enclosed tasks tapping complex ("representational") visuospatial abilities: recognition of abstract figures (Caltagirone et al., 1993), or mental assembly of geometric figures (Mack & Levine, 1981).

On these grounds, we aimed at searching for the "missing link" between visuospatial and constructional abilities in a study on normal subjects and on a selected group of focal brain damaged patients without severe cognitive defects. Moreover, to avoid the possible bias introduced by the selection of a single measure of visuospatial abilities we assessed a wide range of perceptual and representational abilities, by means of a battery of tasks not requiring a motor response.

METHODS

Participants

We tested a consecutive sample of focal brain-damaged in-patients from three Rehabilitation Institutes. To be eligible for participation in the study, patients needed to have experienced a single ischemic or hemorrhagic brain lesion evident on CT scan. Patients with unilateral spatial neglect and general intellectual impairment were not suitable for participation (see below). Moreover, we excluded LBD affected by severe language comprehension disturbances. Subjects with no formal education were also excluded, on the basis of the well-known impact of illiteracy on nonverbal neuropsychological performances (for a review, see Rosselli & Ardila, 2003).

One-hundred twenty-five normal volunteers, without history or signs of neurological or psychiatric diseases, participated in the experiment as the control group.

Materials and Procedure

For selecting eligible subjects, all consecutive focal brain damaged patients were tested on two tasks of visual exploration: line cancellation (Pizzamiglio, Judica, Razzano & Zoccolotti, 1989; two or more omissions on the same side are considered an index of unilateral spatial neglect) and star cancellation (Halligan, Marshall, & Wade, 1989; five or more omissions on one half of the page are considered an index of neglect). LBD were also assessed on a language comprehension test (Token test, De Renzi & Faglioni, 1978; a score <17/36 can be considered as an index of severe verbal comprehension defects). Moreover, RBD patients were tested on a verbal abstract-reasoning task (verbal abstract judgement test; Spinnler & Tognoni, 1987) and LBD completed a visuospatial task for logical thinking (Raven Progressive Matrices; Raven, 1982). Both tests were administered according to general instructions standardized on an Italian adult sample, which enables identification of pathological performances with respect to age- and education-adjusted norms (Spinnler & Tognoni, 1987).

Twenty-four RBD and 22 LBD met inclusion criteria. All patients had a variable degree of unilateral paresis, 8 of them (4 RBD and 4 LBD) had unilateral visual field defects. These patients then underwent a second session comprising a test of general cognitive abilities (Mini-Mental State Examination; Folstein, Folstein, & McHugh, 1975), and a drawing test to assess constructional abilities: the copy of the Rey-Osterreith complex figure Osterreith, 1944; Rey, 1941; see Trojano, DeCicco, & Grossi, 1993, for a study on brain-lesioned patients). The Rey-Osterreith complex figure has been extensively used to assess drawing abilities in normal subjects and to diagnose 'constructional disorders' (as meant by our operational definition) in several patient samples; in the present article we will adopt the original 36-point scoring system, that has a high interrater reliability (see Lezak, 1995 for a review).

Subsequently, all selected patients completed the Battery for Visuospatial Abilities (BVA, known in Italy as TERADIC; Angelini & Grossi, 1993). The battery comprises two sections exploring visuospatial perceptual and representational abilities, by means of a harvest of tasks used in previous research and clinical studies (for reviews see Lanca, Jerskey & O'Connor, 2003; Lezak, 1995), and adapted to make administration and scoring procedures homogeneous. The original standardization and normative study (Angelini & Grossi, 1993) demonstrated that educational level affected performances on all tasks. The BVA has already been used both in single case studies (Papagno, 2002; Trojano & Grossi, 1998) and in a study on degenerative cognitive disorders (Grossi et al., 2002). The single tasks of the BVA are described below and are displayed in Figure 1.

Perceptual abilities

This section comprises four tasks assessing visuospatial analysis abilities. These tasks have the format of four-choice recognition, with stimuli presented on the left and the four-choice display presented on the right. Items are presented one at a time and subjects have to point to the only item identical to the stimulus among the distracters, without time constraints. Each correct response is scored 1 point.

1) Line length judgement. This task includes 20 items; the subject has to identify in the four-choice display the line with the same length as the stimulus. Items are of increasing complexity as the linear differences

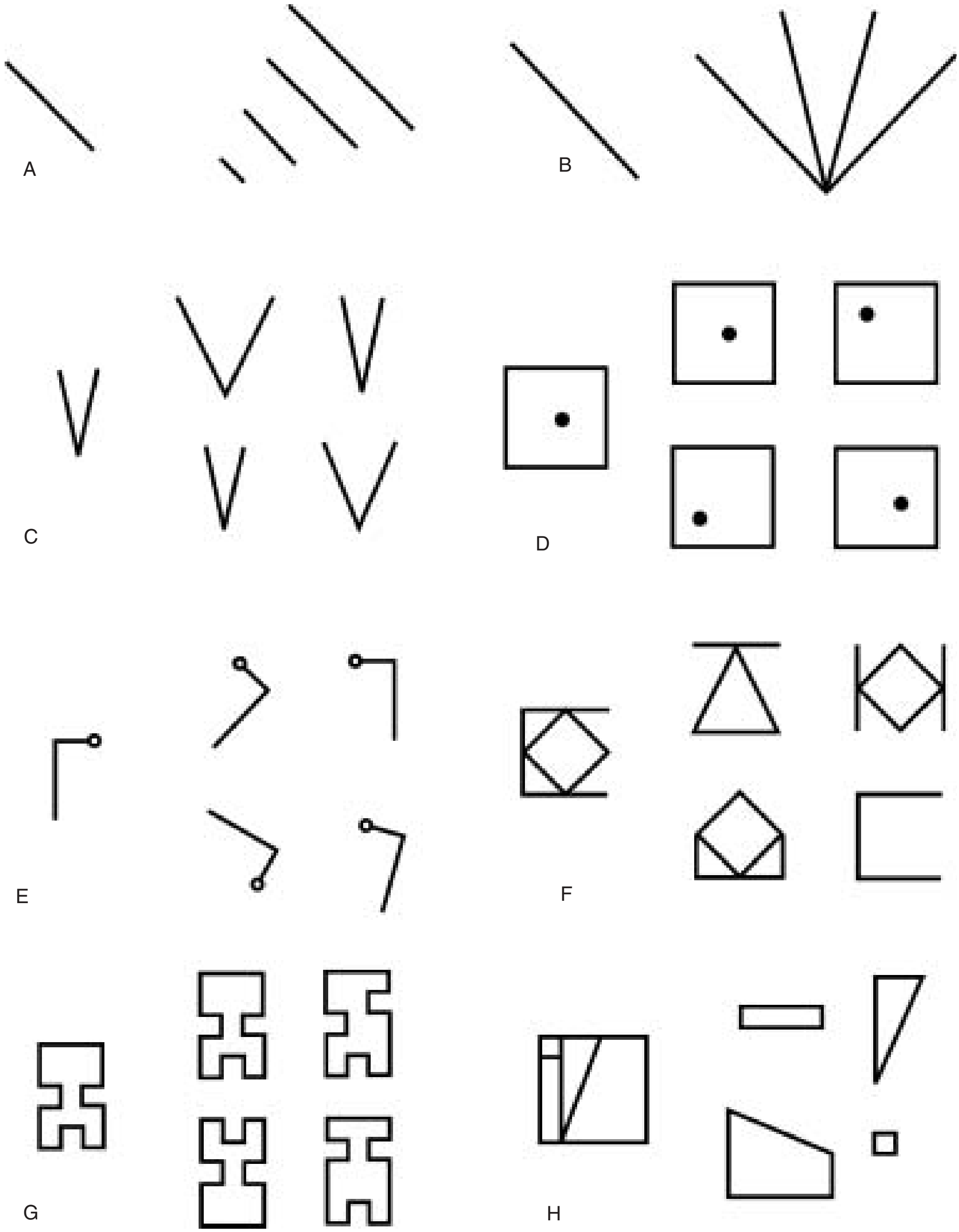

Fig. 1. Examples of the tasks enclosed in the BVA. A: line length judgement; B: line orientation judgement; C: angle size judgement; D: point position identification; E: mental rotation task; F: figure recognition; G: hidden figure identification; F mental construction task.

among stimuli and distracters gradually decreases (score range: 0–20).

2) Line orientation judgement. It includes 10 items; the subject has to identify in the four-choice display the line with the same orientation as the stimulus presented on the left side. In half of the items, the difference in orientation between stimulus and distracters is 30°; in the remaining items the difference is 15°. In the first 7 items, distracters (of the same length as the stimulus) are presented in an ordered spatial arrangement, as in the Benton, Hannay and Varney (1975) test, while in the last 3 items distracters are randomly spread on the four-choice display (score range: 0–10).
3) Angle width judgement. This task includes 10 items; the subject has to identify in the four-choice display the angle with the same width as the stimulus (an angle) presented on the left side. Distracters differ for 15° to 90° from the stimulus (score range: 0–10).
4) Point position identification. The stimuli (*n*= 12) consist of squares containing 1 to 3 points; the subject has to identify in the four-choice display the square with the point(s) in the same position as in the stimulus. Distracters have the same number of points of the stimulus but in different spatial arrangement (score range: 0–12).

Representational Abilities

This section comprises four tasks which require subjects to mentally represent spatial relationships. The first three tasks of this section have the same four-choice recognition format as the tasks of the previous one; each correct response is scored 1 point. The last one has a different arrangement.

1) Mental rotation. The 10 stimuli are shaped as the capital letter L (*n*=5) or as an italic capital S, with small white or black circles at the extremities. The four-choice displays enclose the stimulus item, rotated by 45°, 90°, 135° or 180°, together with three distracters, made by mirror forms of the stimulus and printed at different degrees of rotation. The subject is required to mentally rotate the stimulus on the horizontal plane, and to identify the only item in the display that matches it. Prior to the task, the subjects receive two practice trials aided by use of solid stimuli (score range = 0–10).
2) Complex figure identification (shape recognition). The 10 stimuli consist of nonsense geometrical shapes of increasing complexity, not easily described verbally; the subject has to identify in the four-choice display the only figure matching the stimulus presented on the left side. Also in this case, two practice trials are given before the task (score range = 0–10).
3) Hidden figure identification. The 10 stimuli consist of nonsense geometrical patterns of increasing complexity. For each stimulus, the display includes four complex geometrical patterns; the subject has to identify among the alternatives the only pattern exactly embedded in the stimulus. The subject has to analyze and disassemble each stimulus in his/her mind to give the correct answer. Two practice trials are given (score range = 0–10).
4) Mental construction. The 10 stimuli for the mental construction task consist of squares randomly subdivided into four parts. The four components of each stimulus are randomly placed in the display; the subject is required to identify with which side two components named by the examiner are contiguous in the stimulus. To give the correct answer, the subject has to mentally assemble the stimuli. Two practice trials with solid stimuli are given prior to the task. Two questions are foreseen for each trial; each correct response is scored 1 point (score range= 0–20).

Statistical Analysis

The analysis of variance and the Student *t* test, as appropriate, were used to compare demographic characteristics of the three groups. Analysis of covariance, with age and education as covariate, was used for comparison of controls' and patients' means on constructional and visuospatial tests. Post-hoc comparisons were made by means of Scheffe's test. Level of significance was set at p = .001 according to Bonferroni's adjustment for multiple comparisons.

Pearson's correlation coefficients were calculated to verify relationships between perceptual and representational visuospatial abilities and constructional test scores and the other neuropsychological measures in each group. Stepwise multiple regression analysis was used to take into account interactions among independent variables.

Comparisons of distributions of drawing procedures for the Rey complex figure were performed by chi square analysis.

RESULTS

Characteristics of subjects and their scores on MMSE and Rey figure are reported in Table 1. Mean age and mean education did not differ between the two patient groups of brain-damaged patients.

Normal subjects achieved significantly higher scores than both patient groups on MMSE and on the copy of Rey figure. The qualitative analysis of Rey figure copying procedures showed that the large majority of normal subjects (75/125, 60%) adopted a global approach (procedures I and II), while 50/125 (40%) choose a piecewise strategy

Table 1. Subjects' Characteristics and Scores.

Measure	Max score	Controls	LBD	RBD	F	p
N		125	22	24		
Male/Female		65/60	19/3	21/3		
Age, yr.		64.7±10.8	58.9±14.8	60.6±13.8	<1	.7
Education, yr.		10.9±4.5	7.6±3.6	7.1±4.4	<1	.7
Duration of disease, mos.		-	26.0±37.2	29.9±33.0	<1	.5
MMSE	30	26.9±2.9	23.3±3.8*	24.5±3.4*	8.1	.0006
Rey figure copy	36	26.7±5.4	15.2±8.5*	16.5±8.6*	44,4	<0,001
BVA perceptual tasks						
Line length	20	15.9±1.9	14.1±3.1	14.5±2.2	5,7	0,004
Line orientation	10	6.9±2.1	5±2.2	4.7±2.3*	9,6	0,001
Angle width	10	5.1±1.9	3.0±1.9*	2.4±1.2*	21,7	<0,001
Point position	12	10.5±1.9	9.1±3.1	9.4±2.1	2,9	0,06
BVA representational tasks						
Mental rotation	10	6.9±2.4	5±3.1	5.4±3.1	3,5	0,03
Figure identification	10	8.6±1.7	7.4±2.3	6.7±1.9	7,4	0,008
Hidden figures	10	7.0±2.3	4.4±2.5	3.5±2.6*	19,1	<0,001
Mental construction	20	17.7±2.8	9.9±4.8*	9.6±4.7*	73,0	<0,001

Note. LBD= Left brain-damaged patients; RBD= Right brain-damaged patients; BVA= Battery for Visuospatial Abilities. *means different from healthy control group on Scheffé post-hoc comparisons. No difference between the two patient groups reached statistical significance.

(procedures III and IV according to Osterreith, 1944). In the patient groups, most LBD (16/24; 66.7%) and RBD (17/22; 77.3%) patients adopted a piecewise approach; while only a minority of them choose a global strategy (procedures I and II: 20.8% of LBD and 13.6% of RBD); a few LBD and RBD patients produced scrawls or not recognizable drawings (12.5% and 9.1%, respectively). The distribution of drawing procedures was significantly different in patients and controls (chi square = 33.9, df = 4, *p* = .0001), but it did not differ between the two patient groups (chi square< 1).

Normal controls outperformed both patient groups on perceptual and on representational tasks of the BVA (see Table 1). Post-hoc comparisons revealed that both patient groups scored lower than normal subjects on the angle width and the mental construction tasks, while RBD, but not LBD, achieved scores lower than healthy controls on line orientation and hidden figures tasks. Post-hoc comparisons did not reveal any significant differences between RBD and LBD.

Table 2. Pearson's Correlation Coefficients (*r*) between Rey Figure Copying, and Age, Education and Single Tests of the Battery for Visuospatial Abilities in the Three Groups of Subjects.

	Controls	LBD	RBD
Age	−.501**	−.234	−.196
Education	.240**	.770**	.361
Line length	.265**	.167	.465*
Line orientation	.461**	.594**	.382
Angle width	.320**	.559**	.381
Point position	.216*	.516*	.610**
Mental rotation	.537**	.532*	.514*
Figure identification	.238**	.472*	.391
Hidden figures	.427**	.503*	.261
Mental construction	.369**	.631**	.485*

Note. Level of significance of the simple linear correlation coefficients are shown as follows: *means $p< .05$, **means $p < .01$. The variables that gave a significant contribution to the stepwise multiple regression model are printed in bold.

Rey figure copying was significantly correlated with age, education and all BVA visuospatial tasks on simple regression analysis in normal subjects (Table 2). A similar pattern of simple correlations was observed in LBD, in whom, however, age and the line length score were not correlated with the Rey score. At variance, in RBD only two scores of the BVA Perceptual section (line length and point position) and two scores of the Representational section (mental rotation and mental construction) were significantly correlated with the Rey figure.

Stepwise multiple regression analysis was then applied on the three groups separately, using the single scores on BVA tasks and age and education as independent variables, and Rey figure score as the dependent variable. In normal subjects the general model with 10 independent variables accounted for a large part of variance (R = 0.671; adjusted R^2 = 0.450; F = 9.337; p<0.0001); in the forward stepwise analysis the first variable entered in the model was age (multiple R of .61, adjusted R^2 = .34, F = 13.0, p = .002). The score on mental rotations was the second and last variable giving a significant contribution to the prediction of the Rey score (multiple R = .73, adjusted R^2 = .49, R^2 change = .16, F change = 7.53, p= .012).

In left brain damaged patients the multiple regression model gave a multiple R of 0.821 (adjusted R^2 = 0.658; F = 5.033; p = 0.0067). In the forward stepwise analysis only education gave a significant contribution to the model (multiple R of .77, adjusted R^2 = .57, F = 29.1, p =<.0001).

In RBD the multiple regression model gave a multiple R of 0.810 in RBD (adjusted R^2 = 0.615; F = 3.56; p = 0.035), but the stepwise analysis showed a divergent pattern with respect to LBD. The first variable entered in the equation was the point position score (multiple R = .54, adjusted R^2 = .28, F = 49.8, p < .0001). The mental rotation score was the second and last variable that gave a significant contribution to the equation (multiple R = .63, adjusted R^2 = .39, R^2 change = .11, F change = 22.36, p< .0001).

DISCUSSION

Several previous studies investigated the relationships between visuospatial and drawing abilities, but they did not yield homogeneous results (Carlesimo et al., 1993; Kirk & Kertesz, 1989; Mack & Levine, 1981). This may be because in many instances only one or few spatial tasks were used (for a review, see Grossi & Trojano, 2001). The aim of the present study was to systematically investigate a range of visuospatial abilities in focal brain damaged patients in order to establish whether such relationships do exist. By adopting strict selection criteria, we could study the effect of focal lesions independently from other cognitive defects that can impair performances on visuospatial tasks.

First, our study confirmed that RBD and LBD did not differ on the constructional task both on quantitative basis and on the drawing procedures, after exclusion of patients with general intellectual deficits, severe aphasia and visual exploration deficits. This finding ties in with recent clinical investigations (e.g., Carlesimo et al., 1993, Trojano, De Cicco & Grossi, 1993), and functional brain imaging studies (Makuuchi, Kaminaga & Sugishita, 2003), demonstrating no clear lateralization of constructional abilities.

Second, the analysis of BVA results showed that performances on most visuospatial tasks did not differ significantly between the two patients groups, and in some cases (line length and point position discrimination, mental rotation and shape identification) even the difference between both patient groups and controls did not reach our conservative significance level.

Several caveats must be considered in evaluating these results. Our sample size is similar to that of previous studies (e.g., Caltagirone et al., 1993; Kirk & Kertesz, 1989), but a larger patient sample could magnify the nonsignificant trends observed in the present study. Moreover, modifications of task parameters might generate different patterns of results; for instance, a recent investigation has shown that performances of focal brain damaged patients on point position localization tasks are affected by several factors inherent to stimulus presentation (Postma, Sterken, de Vries, & de Haan, 2000). Our "negative" findings may also be explained by the narrow selection criteria according to which we enrolled only brain damaged patients without severe cognitive disturbances for this study. Nonetheless, the angle size judgement and the mental construction tasks well discriminated patients and controls, while on the line orientation and the hidden figure tasks RBD, but not LBD, performed significantly worse than control subjects.

Our hidden figure task required subjects to identify abstract patterns embedded within more complex nonsense geometrical patterns. This task has been devised for the specific purpose of verifying the ability to carry on fine-grained spatial discrimination and analysis, and is not intended to rely on configurational shape identification as in so-called “ventral stream” tasks (Chen, Myerson & Hale, 2002). Therefore, our hidden figure task is best conceived as a task with prominent load on spatial analysis and representational skills. Likely, the heavy load on perception and discrimination of stimuli’s physical and spatial properties could account for the poor performances by RBD group. This finding is consistent with previous studies in which similar tasks have been employed (De Renzi & Spinnler, 1966). A specific defect of RBD on line orientation tasks has been repeatedly reported (see Hamsher, Capruso & Benton, 1992), but no effort was made in such studies to disentangle the contribution of defective visual exploration. In the research by Mehta, Newcombe and Damasio (1987) and Mehta and Newcombe (1991) LBD and RBD groups were not affected by overt defects of visual exploration or of general intelligence, as it can be inferred by their normal scores on Raven’s Progressive Matrices (1982), and therefore their results could be more easily comparable to the present findings. Mehta et al. (1987; 1991) reported LBD defective performances on orientation judgement tasks, while RBD patients were found to be impaired in an angle matching task. Thus, our findings are inconsistent with those of Mehta et al. (1987; 1991). The discrepancy could be explained by the different assessment methodology and also by peculiarities of Mehta et al’s patients sample (aged men with penetrating missile wounds that had been sustained decades before testing; see Hamsher, Capruso & Benton, 1992). A recent study in which line orientation judgements have been assessed in RBD and LBD not affected by unilateral spatial neglect or aphasia has confirmed the trend of RBD to achieve scores lower than LBD (Ng et al., 2000).

Our mental construction task is quite similar to the Form Assembly Task by Mack and Levine (1981), but in our case no physical assembling of square subcomponents is required. Mack and Levine (1981) reported that LBD performed better than RDB on their constructional task and also on a line length and on an angle size discrimination task. However, once again no attempt was made to exclude patients with visual exploration defects.

Nonetheless, Mack and Levine’s results (1981) are in keeping with our third and main finding, that constructional performances are significantly correlated with visuospatial perceptual abilities in RBD, but not in LBD. However, our results appear to be more specific because we assessed a wide range of visuospatial abilities, and for most of them LBD and RBD groups’ performances were very similar.

Taken together, these results suggest that no strong functional lateralization exists as regards both elementary visuospatial perceptual abilities and abstract spatial representational skills. RBD and LBD performances did not differ even on the constructional test. However, the severity of visuospatial disturbances was correlated to constructional abilities in RBD and not in LBD. It is worth underlining that both a measure of spatial “perceptual” abilities (point position discrimination) and an index of the (“representational”) ability to manipulate spatial information (mental rotation) were significantly correlated to constructional skills in patients with right brain lesions; this finding suggests that multiple aspects of spatial processing are engaged in constructional tasks and can affect drawing accuracy in RBD. The same representational task (mental rotation) was significantly correlated with accuracy in copying the Rey figure also in our sample of healthy controls. On this basis, it is possible to speculate that spatial representational abilities may be critical in the analysis of complex stimuli, which is necessary to plan the graphic production (Grossi & Trojano, 2001). The lack of significant correlations in LBD could be explained by the additional weight of other factors, not explored by the present study.

From a theoretical perspective, these findings would support the idea that visual perceptual and representational abilities do play a role in constructional abilities. At variance with Carlesimo et al.’s study (1993), we demonstrated a relationship between the graphic reproduction of geometrical figures and specific spatial abilities in brain damaged patients, by means of tasks that did not require any motor output. By evaluating a wide range of spatial abilities we succeeded in establishing a link between visuospatial abilities and constructional skills, at least in RBD. Therefore, our data are congruent with recent theoretical models of drawing that foresee that "general purpose" spatial perceptual abilities are involved in constructional tasks (Guérin, et al., 1999), but also that abstract spatial representational skills may play a role in planning graphic productions (Grossi & Trojano, 2001). While specific single-case studies can identify patients with specific impairments in constructional abilities (Trojano & Grossi, 1998), right focal brain damaged patients may show deficit in constructional tasks related to impaired visuospatial processes.

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