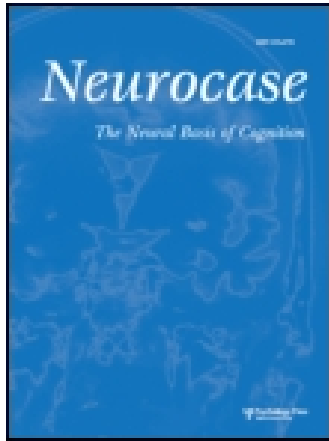


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A stimulus-centered reading disorder for words and numbers: Is it neglect dyslexia?

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A single case, RCG, showing a unilateral reading disorder without unilateral spatial neglect was studied. The disorder was characterized by substitutions of the initial (left) letters of words, nonwords and Arabic numbers, independently of egocentered spatial coordinates. MRI showed a bilateral lesion with the involvement of the splenium. Although, within the framework of the visual word recognition model proposed by Caramazza and Hillis (1990), RCG disorder could be defined as a stimulus-centered neglect dyslexia, we discuss the hypothesis of a dissociation in neural correlates and mechanisms between the syndrome of unilateral spatial neglect and such a unilateral reading disorder.

Introduction

The present study investigates the case of a patient with a specific reading disorder affecting the elements in the initial left-sided positions in both letter and Arabic number strings. Several cases of reading disorders affecting a spatial dimension of the visual field or of the stimulus itself have been described and classified under the term “neglect dyslexia” (see, e.g., Kinsbourne and Warrington, 1962; Ellis *et al.*, 1987). This disorder is often one of the symptoms of unilateral spatial neglect, a neuropsychological syndrome whereby patients fail to detect or identify objects, or to execute movements in the portion of space contralateral to the side of the lesion, with reference to a specific coordinate frame. The disorder is more frequent and severe after damage to the right hemisphere, involving then the left portion of space. The most frequent anatomical correlate of spatial neglect is damage to the right inferior parietal lobule (supramarginal gyrus), but lesions involving the premotor cortex, or confined to subcortical lesions, may also be associated with neglect (Vallar, 1998; Bisiach and Vallar, 2000; Halligan *et al.*, 2003). There is general agreement that unilateral spatial neglect, far from being a unitary disorder, consists of a multifarious deficit that may affect different frames of references (e.g., egocentric and

allocentric), internal representations and space location (e.g., near and far space).

Studies on word processing have shown that the transformation of a visual written stimulus into a representation in which lexical and semantic information is available proceeds through several steps and that neglect dyslexia may arise at different stages of such a process. In the word recognition model proposed by Caramazza and colleagues (Caramazza and Hillis, 1990; Hillis and Caramazza, 1990, 1991, 1995; Rapp and Caramazza, 1991; Hillis *et al.*, 1998), the process of visual word recognition is hierarchically organized through several levels, each characterized by specific elements and frames of reference. Patients may suffer damage at each of these levels, giving rise to the varieties of deficit reported in the literature. At the first level, referred to as retinocentric, basic stimulus features are detected and localized in reference to a spatial coordinate system centred on the eye fixation point. Damage at this level normally results in a loss of ability to report information presented in the visual hemifield contralateral to the lesion. Deficits at this level of representation have been extensively described both in group studies (see, e.g., Làdavas *et al.*, 1997; Arduino *et al.*, 2002, 2003) and single cases: MO (Riddoch *et al.*, 1990), JOD (Hillis and Caramazza, 1995) and EB (Vallar *et al.*, 1996).

At the second level, known as stimulus-centered, shapes emerge from grouping processes and left and right are defined with respect to the center of the global stimulus. The technique of presenting tachistoscopically the stimuli at different locations in the visual field allows distinguishing between a retinocentric and a stimulus-centered deficit. This latter deficit has been reported for several patients (SP, Young *et al.*, 1991; VB, Ellis *et al.*, 1987; BPN, Hillis and Caramazza, 1995; Cubelli *et al.*, 1994).

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At the last level of word processing postulated by Caramazza and Hillis (1990), namely the word- or object-centered reference frame, single letters are identified independently of formal characteristics (e.g., font, case), orientation in the visual field (horizontal, vertical or mirror-reversed) and task (reading, writing and spelling). At this level of representation, left and right are defined according to the canonical representation of the word. Several patients with disturbances at this level of word recognition processing have been described (NG, Caramazza and Hillis, 1990; HH and RB, ML, Hillis and Caramazza, 1995a; JL, Barbut and Gazzaniga, 1987; ORF, Baxter and Warrington, 1983; SVE, Miceli and Capasso, 2001).

In all the cases mentioned, irrespective of the representational level of impairment (retinocentric, stimulus-centered or word-centered), neglect dyslexia principally affects the contralesional side of space (external or internal, such as in the case of word-centered neglect) and is habitually associated with spatial neglect. However, in recent years several spurious cases have been described, in which a reading disorder occurred consequent to damage to the left hemisphere affecting the left side of space (ipsilesional). In 1989, Katz and Sevush reported the case of JM, a patient with left-hemisphere lesion and right upper quadrantanopia, who produced position-specific errors in word reading. The patient showed visual extinction and difficulties in the right visual field, whereas the reading disturbance was ipsilesional. The reading errors, which affected the beginning (left side) of words, appeared also when the string was presented tachistoscopically in different locations of the visual field or when vertically oriented. Similarly, Patterson and Wilson (1990) described a patient, TB, who, after left posterior hemisphere stroke, produced reading errors that mainly affected the first elements of printed words and digits. Both patients were unimpaired when tested for visuo-spatial neglect, though JM (Katz and Sevush, 1989) showed a mild visual extinction on the right visual field. More recently, Haywood and Coltheart (2001) reported the case of RR, a patient with a bilateral lesion, involving principally the left hemisphere, who showed no signs of unilateral spatial

neglect but had a reading disorder characterized by errors in the initial letters of both words and Arabic numbers. Analogously, Cohen and Dehaene (1991) described the case of YM, a patient with a left-lesion, who presented visuo-spatial behaviour akin to neglect dyslexia when reading Arabic numbers, with most of the errors occurring on the left side of number strings (first digit).

In the present study RCG was tested by means of a complete neuropsychological assessment and four experiments in order to define and explain his reading disorder for left-side letters and digits. A comparison between the present case and the other similar cases described in the literature (JM, Katz and Sevush, 1989; TB, Patterson and Wilson, 1990; YM, Cohen and Dehaene, 1991; RR, Haywood and Coltheart, 2001) led us to suggest the existence of a specific stimulus-centered reading disorder which differed from neglect dyslexia for two main reasons: the neural correlates and the underlying mechanism.

Case History and General Neuropsychological Examination

RCG, a 72-year-old-right-handed architect with 18 years of education, has suffered multiple ischemic strokes over the last ten years. He participated in tests from October 2002, after the last stroke that occurred in April of the same year, till the end of 2003. The last MRI showed several infarcts bilaterally in the temporo-parietal areas, diffuse atrophy of the white matter; the splenium and the paraventricular area were both affected. SPET revealed an hypo-perfusion in the left temporo-parietal area and a moderate deficit in the left occipital area (see Figure 1).

Visual field examination disclosed a right upper quadrantanopia (tested by Kinetic Goldmann perimetry). Standardized neurological examination (Bisiach and Faglioni, 1974; Bisiach and Vallar, 2000) did not provide evidence of extinction of visual and tactile stimuli. Constructional abilities were spared. Spontaneous speech and comprehension were preserved with no

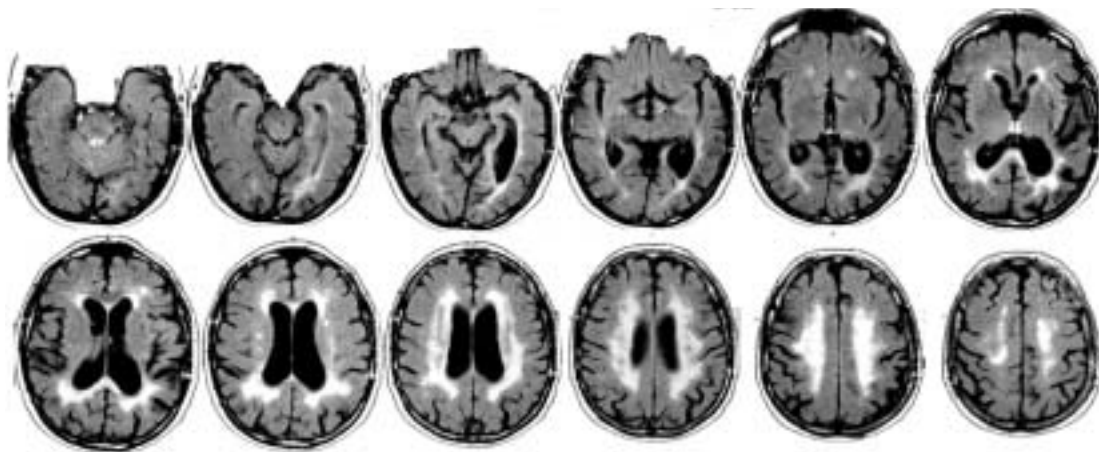


Fig. 1. Representative sections of the magnetic resonance imaging scan.

aphasic symptoms. The patient had some difficulty in retrieving information from long term memory. He did not show ideomotor or utilization apraxia. A complete examination revealed no signs of intellectual deterioration. From a preliminary analysis it emerged that RCG had difficulty in reading letters and numbers aloud. His performance on a visual perception battery (VOSP, Warrington and James, 1991) was in the normal range except for the incomplete letters test (10/20) and two space perception tests (dot counting and number location). See Table 1.

Reading numbers aloud

On a test normally used to assess arithmetical abilities (Basso and Capitani, 1979), the patient obtained a pathological score (score: 26/101; cut-off: 74/101). In the first test, which was composed of 36 numbers, from 1 to 5 digits long, ordered into three rows and 12 columns, he failed to read aloud the digit strings correctly, indicating that his reading errors mostly involved the digits located on the left side of the digit string (10/30 errors; e.g., 63 read as 93). The other tests included mathematical operations such as addition, subtraction, multiplication and division. The patient's performance on all these operations was very poor and his errors were clear manifestations of his difficulties in reading the elements which occupied the left side of a digit string.

Reading letters aloud

The overlapping figures test (BORB, Riddoch and Humphreys, 1993) showed that the patient's reading deficit also involved letters. In this test, each page contains 10 elements, paired and triplets of letters, geometric features and objects, ordered in three rows. RCG failed on letters only, substituting the left-side letter (e.g. VL read as EL)¹ (see Table 2).

The patient was then requested to read aloud single words and nonwords from the reading test by Vallar *et al.* (1996) in order to further evaluate the letter identification problem. The test included two lists composed of 38 words and 38 orthographically legal nonwords. The word list comprised 30 four-to-nine letter words (five for each item length), three 10-letter words,

three 11-letter words, and two 12-letter words. The mean frequency of the words, selected from a corpus of Italian written language of 1.5 million tokens (Istituto di Linguistica Computazionale, CNR, 1989), was 13.71 (range 0–47). The orthographically legal nonwords were obtained from the 38 words by changing one letter in the left half of each letter string (e.g., the nonword *carrocchia* was obtained from the word *parrocchia*—parish). Each stimulus was printed horizontally in the center of a 29.7 cm × 21 cm white sheet in black uppercase letters (24-pt Geneva bold laser print). RCG made 2/38 errors in reading aloud words and 5/38 errors in reading nonwords. In all cases, errors consisted in substituting one or two letters which occupied the initial left-side positions.

Visuospatial processing

At first glance the disorder in reading aloud letter and digit strings resembles a left side neglect dyslexia reading disorder. Visuo-spatial abilities were thus assessed by means of a diagnostic battery of unilateral spatial neglect (Zoccolotti *et al.*, 1989) and other orientation and constructional abilities tasks. The diagnostic battery included two barrage tests (Line Cancellation, Albert, 1973; Letter Cancellation, Diller and Weinberg, 1977) requiring the patients to find and cross targets spread across the whole visual field², a Reading Test (Zoccolotti *et al.*, 1989) in which the patient is requested to read aloud six sentences of different length and written character size (the score is the number of incorrectly read sentences, range = 0–6), and a test requiring an overall perceptual judgment of length, the Wundt-Jastrow Area Illusion test³ (Massironi *et al.*, 1988). In all tests, the display was centered on the mid-sagittal plane of the patient's trunk; he was free to move his head and eyes (see a detailed description in Pizzamiglio *et al.* 1989; Zoccolotti *et al.*, 1989). In

Table 1. VOSP-Visual perception battery. Number of correct answers

VOSP (Object perception)		Cut-off	Pathological
Screening test	19	15	
Incomplete letters	10	16	+
Silhouettes	19	15	
Object decision	15	14	
Progressive Silhouettes	16	15	
Space perception			
Dot counting	3	8	+
Position discrimination	19	18	
Number location	6	7	+
Cube analysis	8	6	

¹In all cases, even in reading triplets of letters, the patient's reading errors involved the first letter on the left.

²The Line cancellation (Albert, 1973) test is made of a sheet of paper where 21 black lines, oriented and located in random order, are printed. The subject's task was to mark all the lines. The scores were the numbers of omissions in the left- (range = 0–11) and right- (range = 0–10) sides of the sheet. Normal subjects perform this task without errors. In the Letter cancellation test (Diller and Weinberg, 1977) the subject is presented with six lines of letters and is required to mark all the 'H'. The scores were the numbers of omissions on the left- (range = 0–53) and right- (range = 0–51) sides of the sheet. The maximum number of omission errors for normal subjects is four, and two is the maximum difference between errors on the two sides of the sheet (Vallar *et al.*, 1994).

³It is made of 40 stimuli, each made out of printed illusory configuration: two identical black curves, shifted one in reference to the other, are seen of different lengths. The figures are horizontally oriented, can be of four different sizes, two different directions of the illusory effect (left and right), and two directions of curving (up and down). The subject's task was to judge which of the curved lines was longer. The score was the number of responses not showing the illusory effect ('unexpected'), arising from the left (range = 0–20), and right (range = 0–20) sides of the stimulus. Patients with right brain damage and left neglect make errors only on stimuli with a left-sided illusory effect.

Table 2. BORB- Overlapping figures. Number of correct answers in letters, geometric shapes and objects naming

	Single	Paired (overlapping)	Paired (non overlapping)	Triplets (overlapping)	Triplets (non overlapping)
Letters	35/36	26/36*	24/36*	30/36*	31/36*
Geometric shapes	35/36	36/36	36/36	36/36	36/36
Objects	40/40	39/40	40/40	40/40	40/40

*refers to pathological scores

Table 3. Baseline assessment for visual spatial neglect. Scores: i) cancellation tasks: omission errors; ii) Wundt-Jastrow area illusion test: “unexpected” responses; iii) reading task: the number of sentences in which the patient showed left-sided errors. * = performance indicating left neglect; L: left; R: right.

	Letter cancellation		Line cancellation		Wundt-Jastrow		Sentence eading
	L	R	L	R	L	R	errors
Errors	0/53	0/51	0/11	0/10	12/20*	0/20	0/6

Table 3, the results of the baseline neuropsychological assessment are reported. As shown by the Table, the patient performed quite well in all tasks except for the W-J Area Illusion test, in which errors occurred only when the illusion arose from the left side (we will discuss this further on).

The other visuo-spatial tests included Line Bisection⁴ (B.I.T.: Wilson *et al.*, 1987), the Landmark test⁵ (Capitani *et al.*, 2000) and the Brentano-Muller-Lyer illusion bisection task (Vallar *et al.*, 2000; Daini *et al.*, 2002). This last test consists of a red horizontal line in which the perceived midpoint is shifted due to black inward and outward fins placed at the center and the ends of the line. Three conditions (the illusion towards the left side, the illusion towards the right side and the simple line) for each of the three line lengths (8, 16, 24 cm) were presented. The subjects’ task was to mark the midpoint of the red horizontal line, using a soft pen, with no instructions about the fins being provided. Deviations from the objective midpoint of the red line were measured to the nearest millimeter. The difference between the illusory configuration and the simple line gave the presence and the amount of the illusion for each side of space. Patients with

⁴The subject is required to mark the midpoint of three lines: one shifted on the right side of the sheet, one aligned with the center and the third shifted on the left side.

⁵It is made out of pre-bisected horizontal lines. Two sets of stimuli were presented. In one set the subject’s task was to identify which of the two segments composing the line was the longer/shorter (motor Landmark); in the other set the two segments were of different colors and the subject had to name the color of the longer/shorter segment (verbal Landmark). For the scoring see Capitani *et al.* (2000).

right brain damage and left neglect showed illusory effects on both sides when hemianopia was not associated. RCG was susceptible to the illusion on both sides of space (averaged bisection errors: 8.14 mm on the left and 7.80 mm on the right for the left-hand illusory expanded figure and right-hand illusory expanded figure respectively). No systematic bias was found in either the Standard Line Bisection or the Landmark Test.

In conclusion, the visuo-spatial assessment showed no evidence of the presence of visuo-spatial neglect, although the patient’s performance on the Wundt-Jastrow Area Illusion test was pathological.

Experiment 1

Reading Aloud Words and Nonwords

The purpose of this experiment was to qualify and quantify the reading impairment of RCG by presenting him with single words and nonwords to be read aloud.

Materials and procedure

The reading list was composed of 240 stimuli (120 words and 120 nonwords; mean length: 6.0, range: 5–8). The stimuli (black uppercase letters, 24-pt Geneva bold, printed in the center of an A4 sized sheet of white paper) were presented for an unlimited length of time. More than one stimulus was printed on each page, so a moveable window was used to present one letter string at a time. The patient was informed that he could take his time to respond. The center of each stimulus was aligned with the mid-sagittal plane of the patient’s trunk.

The patient knew that the target could be a word or a nonword and was instructed to report it as accurately as possible, regardless of its lexical plausibility. No feedback was given. Words and nonwords were randomly distributed across seven blocks (five blocks of 34 stimuli and two of 35).

Error Classification. As pointed out before, the vast majority of RCG’s reading errors involved the elements which occupied the initial left-side positions of letter strings. The errors were divided into three types: (i) No response; (ii) Paralexical errors involving the initial left-side positions, further classified

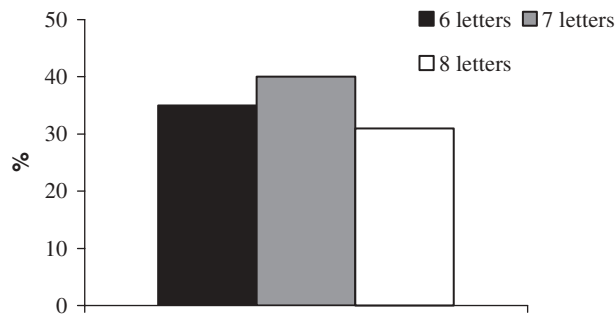


Fig. 2. Percentage of reading errors regarding the initial left-hand position with respect to stimulus length.

as letter substitutions, omissions and additions. The letters on the left-side could be substituted in such a way that target and error maintained the same length [e.g., the word *cuore* (heart) read as *suore* (nuns)]; they could be omitted so that the response was shorter than the target (e.g., the word *chimera* (chimera) read as the nonword *imera*), or added in such a way that the response was longer than the target [(e.g., the word *nastro* (ribbon) read as the word *disastro* (disaster)]; (iii) Visual errors, in which errors could occur in positions other than the initial position [e.g., target word: *adulto* (adult) resulting in *auto* (car)].

Results

In reading the 240 stimuli aloud, patient RCG made 165/240 reading errors (69%). The error analysis showed that 76% of his errors (125/165) involved exclusively the left-side letters [more specifically, 98/125 (78.5%) errors involved one left-side letter and 27/125 (21.6) two left-side letters]. A further analysis showed that the vast majority of errors were letter substitutions (substitutions: 106/125 (85%); omissions: 19/125 (15%); $p < .0001$, binomial test), more often elicited by nonword than word targets (word target: 40/125 (32%); nonword target: 85/125 (68%), $p < .0001$). Moreover, the patient errors consisted mostly on words as opposed to nonwords (word responses: 84/125 (67%); nonword responses: 41/125 (33%); $p < .0001$).

If the deficit concerning the left initial letters were related to a retina-centered level, an increase in reading errors in proportion to the increase in stimulus length would have been expected, due to the fact that at this stage, the elements in the written input string are coded in terms of their absolute position in the visual field. The greater the length of the letter strings, the higher the number of elements occupying the left hemifield. However, as shown in Figure 2, where the percentage of reading errors affecting the left side letters with respect to stimulus length is reported, reading errors did not increase significantly with the increase in stimulus length [17/48 errors on 6 letter strings; which is not statistically different from the 27/68 errors made on 7 letters ($\chi^2 = .22$, $df = 1$, $p > .1$) or from the 5/16 errors made on 8 letters ($\chi^2 = .09$, $df = 1$, $p > .1$); nor is the difference between errors made on 7 and 8

letters significant ($\chi^2 = .39$, $df = 1$, $p > .1$)]. Stimuli of 5 letters were excluded from these length analyses as they were constructed in such a way as to elicit more errors on the initial positions (see Arduino and Burani, 2004 for a detailed description).

Experiment 2

The results of Experiment 1 showed that when reading single words and nonwords, RCG made errors on the initial left-side letters. These errors were mostly substitutions, so that target and response remained the same length, and apparently were not influenced by stimulus length, suggesting that the reading deficit may affect a spatial reference frame where the representational space is relative to the stimulus.

The question of which spatial coordinate frame was most affected by the deficit was therefore further investigated in Experiment 2. Words and nonwords were presented to the patient in different locations in the visual field (left, center and right), with different spatial orientations (horizontal, vertical and mirror-reversed) and for tasks other than reading, such as copying, writing to dictation and oral spelling. Moreover, in order to better clarify whether the deficit in reporting the letters in the initial left-side positions was due to a more general attentional deficit, the initial elements of letter-strings in this position were printed in larger characters in bold.

Materials

A subset of the original list involving 100 items (50% words and 50% nonwords) was used. The list had the same characteristics as that of Experiment 1. The stimuli were printed in black uppercase letters, 24-pt Geneva.

Experiment 2a: Visual field presentation

As suggested by Subbiah and Caramazza (2000), stimuli must be presented tachistoscopically in the left and right visual fields in order to exclude the occurrence of retinocentric disturbance. If the left-sided reading disorder is relative to the stimulus' coordinate frames, errors should occur *on* the left-side letters of stimulus, irrespective of the location in the visual field. On the contrary, if the deficit affects the retina-centered level, more errors will be made in the first letters of words presented in the patient's left visual field than in his right visual field.

Procedure

Words and nonwords were presented on a computer screen. Each trial began with a 1500 ms fixation point (a cross) in the center of the display screen, and was immediately followed by the target word or nonword that remained on the screen for 400 ms. The experiment was run in three sessions

and stimuli were differently randomized across conditions: the first with the words in the center of the screen, then with the words on the left and then on the right of the screen center. To ensure RCG continued to fixate centrally when reading, his eye movements were monitored by the experimenter, who sat directly opposite him; trials on which RCG was thought to have re-fixated were excluded from analysis.

Results

Less than 0.5% of trials were excluded from the analyses, due to re-fixation. The results showed that RCG made the same number and type of left-sided errors, independent of the positioning of the letter string. He made 37%, 44% and 38% reading errors when reading aloud the 100 stimuli presented centrally, in the left and in the right visual fields, respectively. Moreover, the percentage of errors on the first letters of words and nonwords shown in the three spatial locations are comparable (centrally: 33/37 (89%); left: 41/44 (93%); right: 32/38 (94%). Figure 3 shows the percentage of errors on the first letters of the stimuli compared to the final parts of the stimuli in the three spatial locations. These results suggest that the patient's deficit is relative to the stimulus itself rather than to its spatial location (retinocentric level).

Moreover, we looked at how many left-sided letters were compromised when the stimuli were presented in the three different spatial locations. In Table 4 the number of errors involving one or two letters in the first positions across spatial locations is reported. As shown by the table, the kind of errors is the same across the three conditions.

Experiment 2b: Spatial orientation

Procedure

The same stimuli were subsequently presented vertically and mirror-reversed on a white sheet of paper with a blocked presentation order (canonical-horizontal, vertical, mirror-reversed),

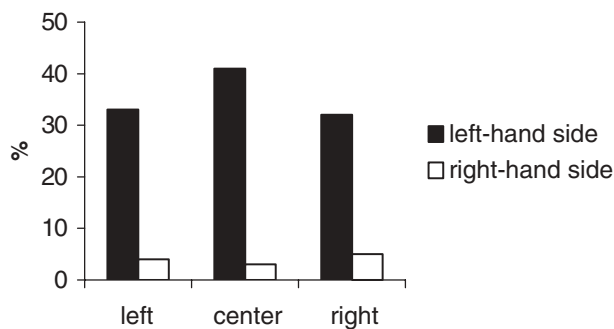


Fig. 3. Percentage of reading errors involving the left and right side of letter strings when stimuli are presented left, centrally and in the right visual field.

Table 4. Experiment 2: Number and percentage of errors in reading words and nonwords at different spatial locations (left, center, right), number of errors involving one or two letters occupying the initial left-side position

	Left-visual field	Center	Right-visual field
Tot errors on the left	33/100 (33%)	41/100 (41%)	32/100 (32%)
1 letter	25/33 (75.8%)	29/41 (70.7)	23/32 (71.9%)
2 letters	8/33 (24.2%)	12/41 (29.3%)	9/32 (28.1%)

in order to define the defective reference frame underlying the left-sided reading disorder (see Caramazza and Hillis, 1990; Hillis and Caramazza, 1990, 1991, 1995; Rapp and Caramazza, 1991; Hillis *et al.*, 1998).

Results

In reading aloud the 100 stimuli presented vertically, the patient made 15 errors (15%), all involving the letters in the first position (e.g., the nonword “zontana” read instead of “lontana” *far*). When the stimuli were presented mirror-reversed, the patient made 16/100 (16%) errors. Fifteen errors (94%) involved the final letters of the target, which still occupy the left-side of the visual stimuli. When a word is presented in mirror-reversed mode, its initial letters are on the right and its final letters on the left. In this experiment, RCG committed errors on the initial (left-side) letters on normally presented words, and when reading mirror-reversed words, he made errors on the final letters. It can therefore be deduced that RCG's disorder involves the identification of the leftmost letters in a visual array (Ellis *et al.*, 1987). The number of errors in reading aloud stimuli aligned horizontally (37/100) is greater than those produced in reading aloud stimuli presented vertically (15/100) or mirror-reversed (16/100). One possible explanation of the difference between the three orientation conditions is that the strategy used for the visual recognition of horizontal stimuli, more usual and automatically processed, is more sensitive to a reading disorder than in the case of vertical and mirror-reversed stimuli.

Within the model proposed by Caramazza and Hillis (1990), the results obtained with vertically and mirror-reversed stimuli may appear in contradiction. The fact that RCG continued to produce errors on the letters in the initial position when the letter strings were aligned vertically may suggest a deficit in the more abstract level of word representation, namely, the object-centered level. However, if this were the case, it would have been expected that in the mirror-reversed format, errors would occur in the initial letters of words which now occupy the right side. This was not the case; RCG made errors on the final letters, which occupied the left-side position in mirror-reversed strings.

A similar result indicating a misreading of the letters which occupy the first position, for both horizontal and vertical presentations, was obtained by JM (Katz and Sevush, 1989). The authors explained the occurrence in terms of a compromised analysis of initial letters instead of letters to the left or right of a canonical representation. Unfortunately, JM was not presented with aligned mirror-reversed stimuli. We would suggest that for RCG, JM (Katz and Sevush, 1989) and TB (Patterson and Wilson, 1990), the deficit involved the initial elements of a letter string and that the results obtained with mirror-reversed stimuli are only apparently in contradiction. Visually, letters on the left are still the initial elements of a letter string even when they are not the initial letters of a word representation. Concerning the vertical stimuli, it could be that at a first level of global visual analysis the letters are reported to a horizontal representation and that mirror-reversed stimuli need another step to be processed.

However, RCG would be impaired before the so-called word-centered level, which includes higher processing levels such as mental rotation.

Experiment 2c: Copy, writing to dictation, oral spelling

The results obtained when words were presented to the patient for tasks other than reading aloud provided evidence supporting the view that RCG's deficit regards the stimulus-center and does not involve the third level, the more abstract object-centered level of representation. Caramazza and Hillis' model (1990), predicted that a deficit located at the object-centered level, which involves the abstract level of words, should emerge in all tasks involving the computation of letter strings, such as writing to dictation and oral spelling.

Procedure

The same list of 100 stimuli was presented for several tasks: i) copy; ii) writing to dictation and iii) oral spelling. The experiment was run in three different sessions, each devoted to a specific task.

Results

Table 5 shows the total number of errors and the percentage of errors involving the letters in the first position in all conditions. It can be seen that RCG made a higher percentage of errors in copying the letter string compared to writing it down or making oral spelling from dictation, which confirms that the deficit is not located at a representational word processing level.

Table 5. Experiment 2 (a) and Experiment 4 (b). Number (in brackets) and percentage of total errors and errors involving the first element positions, on word and nonword strings and digit strings respectively

a) WORD AND NONWORD STRING	Copy	Spelling	Dictation
Tot err.	.15 (15/100)	.02 (2/100)	.02 (2/100)
First position errors	1 (15/15)	1 (2/2)	.86 (1/2)
b) DIGIT STRINGS			
Tot err.	.22 (12/55)	.09 (5/55)	0 (0/55)
First position errors	1 (12/12)	0 (0/5)	0

Experiment 2d: First letter bold

It was hypothesized that the patient's difficulty in reporting the first letter occurs because the leftmost letters do not capture as much attention as the other letters in a string. If this hypothesis is correct, we should expect fewer reading errors when the first letter is more salient. Similar tasks have been used with patients suffering from neglect dyslexia (e.g., VB, Ellis *et al.*, 1987; Riddoch *et al.*, 1990) and the amelioration of the reading performance, depending on the most perceptual salience of the first elements, was taken as evidence that neglect dyslexia, independent of the level at which the deficit arises, is due to a failure in allocating visuo-spatial attention to the left-side (in this case, of a stimulus-centered level of representation). On the contrary, if the deficit cannot be ascribed to an attentional bias to the right, the stimuli in the two conditions (where all the letters are perceptually equal versus the condition in which the first letter stands out from the others) should elicit the same kind and number of errors.

Procedure

The same list was used. The first letter of each stimulus was printed in a larger size (36-pt Geneva) and in bold.

Results

The comparison of the two conditions (with and without the first letter in bold print) supplies no evidence of a decrement of errors in the condition in which the first letter is supposed to draw visuo-spatial attention. RCG made 30/100 reading errors (30%), mostly involving the letter in the first position (29/30, 97%), on the list included the 100 letter strings with the first letter in bold. The result is comparable to the condition in which no manipulation of the first letter was made, when the patient made 37/100 reading errors, mostly characterized by errors in the first letter position (33/37, 89%).

Experiment 3

Reading aloud numbers

The preliminary assessment showed that RCG suffered similar impairment in reading aloud visuo-verbal strings made up of letters and digits. The first two experiments, with words and nonwords, showed that his reading performance was characterized by errors in the initial position of the letter strings, independent of spatial location and stimuli orientation. The next two experiments, which used the same methodology adopted in Experiments 1 and 2, investigated RCG's performance in reading Arabic numbers.

Materials and procedure

The reading list was composed of 197 digit strings (Granà *et al.*, 2004), from 1 to 6 digits long. The stimuli (black uppercase letters, 24-pt Geneva bold) were printed in the center of a white sheet of paper (A4). The procedure was the same adopted in Experiment 1. Digit strings of different lengths were randomly distributed across six blocks (five blocks of 33 stimuli and one of 32). The experiment was run in one session. The patient was requested to read the digit string as a single number.

Error classification

The error classification is the same adopted in Experiment 1.

Results

The patient read aloud 126/197 digit strings (64%) incorrectly. Most of the errors involved the digits which occupied the first positions (102/126: 81%, $p < .0001$). Only 5/102 (4.9%) errors involved two digits, while the rest of errors 97/102 (95.1%) involved the first digit.

Moreover, as in the word reading test, the errors are mostly digit substitutions (substitution errors: 87/102 (85%), omission errors: 15/102 (15%), $p < .0001$). The patient also made some errors on single digits (7/32), by substituting the digit with another one.

Experiment 4

As evidenced in the preliminary assessment, RCG made errors in reading the initial digits of a string made up of Arabic numbers. The aim of the present experiment was to investigate whether the deficit affecting number representation was similar to that reported in reading words.

Materials

The reading list was composed of 55 stimuli (Miceli and Capasso, 1991). The list involved 10 numbers composed of one digit, 15 composed of two digits, 10 of three digits,

5 of four digits, 5 of five digits, 5 of six digits. The stimuli (black uppercase letters, 24-pt Geneva bold) were printed in the center of a white sheet of paper (A4). As in the previous experiment, the patient was requested to read the digit string as a single number. The procedure adopted was the same as in Experiment 2.

Experiment 4a: Visual field presentation

The list was presented to the patient in different locations of the visual field. The patient made 11/55 reading errors (20%) on stimuli presented on the left visual field, 13/55 (24%) on those presented in the center of the field and 10/55 (18%) of those presented on the right visual field. As can be seen in Figure 4, reading errors in all conditions mostly involved the digits on the left side.

Experiment 4b: Spatial orientation

When lists of Arabic numbers were presented in different orientations—i.e., vertically and mirror-reversed—the results were similar to those obtained on letter strings. RCG made 3/55 reading errors on vertically oriented digits, all of which were on the initial digits of the string, whereas he made 11/55 (20%) reading errors on mirror-reversed stimuli where the final digits occupied the left-sided spatial position.

Experiment 4c: Copying, writing to dictation, oral spelling

Table 5(b) reports the total number of errors and the percentage of errors involving the first letter positions. As for letter strings, impairment was evident only in tasks in which there was a perceptive component, as in copying. The fact that most of the errors were made in various positions on the longer digit strings indicates that the high number of total errors in digit spelling is due to memory span; this is confirmed by the absence of errors involving the first letter position.

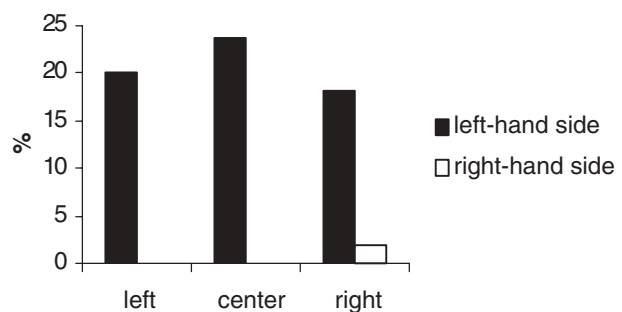


Fig. 4. Percentage of reading errors involving the left and right side of digit strings when stimuli are presented left, centrally and in the right visual field.

Experiment 4d: First digit bold

The condition of attracting visuospatial attention to the initial letters, used for letter strings, was also used for the Arabic numbers test (bold face and with bigger character, see Experiment 2). Comparison of the results from the two conditions provides no evidence of a decrement of errors when the first letter is written in bold. When the 55 digit-strings were presented to RCG with the first element in bold, RCG made 8/55 (14%) reading errors, all affecting the first digits. The results do not differ with respect to the baseline condition, either in terms of the total number of errors (13/55, 24%) or in the percentage of errors involving the first letter (13/13, 100%).

General Discussion

The present study reports the results of a series of experiments performed with a patient, RCG, suffering from a specific reading disorder affecting the initial elements of letter and digit strings, positioned on the left side. In Experiments 1 and 2, single words and nonwords were presented to the patient to be read aloud. Letter strings were presented in canonical format, in the center of a sheet of white paper in A4 format (Experiment 1), in different space locations (center, left and right), with different orientations (vertically and mirror-reversed) and for tasks other than reading, such as copying, writing under dictation and oral spelling (Experiment 2). The patient failed to read correctly the letters located in the initial, left-sided positions of the visual string, irrespective of their location in space and orientation (horizontal vs. vertical). Reading errors consisted mostly in substituting some of the initial letters so that the response and the target maintained approximately the same length. In Experiments 3 and 4, the same procedure was used, but with strings of Arabic numbers. The results were the same as those obtained with letters.

As mentioned before, RCG reacted very similarly to other cases described in the literature such as YM (Cohen and Dehaene, 1991), TB (Patterson and Wilson, 1990), JM (Katz and Sevush, 1989), RR (Haywood and Coltheart, 2001) and JOH (Costello and Warrington, 1987). For all these patients, errors involved the substitution of the left-side initial letters, there was no effect of stimulus length and responses resulted mostly in lexicalizations; moreover, it is interesting to note that the lesions involved at least the left-hemisphere [for RCG, IOH (Costello and Warrington 1987) and RR (Haywood and Coltheart, 2001) a bilateral lesion was reported though the left-hemisphere was more affected, both in anatomical and functional terms]. Katz and Sevush (1989) first made the case for a relation between this type of reading disorder and a certain degree of hemispheric asymmetry; they defined JM's performance on reading aloud as a result of *positional dyslexia* deficit that, similar to previous descriptions (e.g., Bender and Furlow, 1945; Kinsbourne and Warrington, 1962), could be due to damage located entirely in the

left hemisphere. Patterson and Wilson (1990) arrived at the same conclusions, suggesting that this type of deficit reflects a positional specific impairment unrelated to visuo-spatial neglect.

Recently, Haywood and Coltheart (2000) made a review of 19 published single case studies of neglect dyslexia, interpreting them within Caramazza and Hillis's model (1990). Within this model, RCG would have been classified as a patient with significant impairment at the stimulus-centered level of word representation. However, as Haywood and Coltheart (2001) pointed out in their discussion, there can be two types of stimulus-centered deficits. The first, manifested by RR (Haywood and Coltheart, 2001), TB (Patterson and Wilson, 1990), JM (Katz and Sevush, 1989), YM (Cohen and Dehaene, 1991) and RCG, affects the reading system; the locus of the impairment has to be ascribed to a representation of visually presented letter and number strings. The second type is an attentional deficit that affects identification of all kinds of visual stimuli, giving rise to the association of left neglect dyslexia and left unilateral neglect (BPN, Hillis & Caramazza, 1995a; SP, Young *et al.*, 1991; VB, Ellis *et al.*, 1987; Cubelli *et al.*, 1994). However, Haywood and Coltheart (2001) failed to show a relation between these two types of reading disorders and the site of the lesion. In fact, it is interesting to note that these two categories of stimulus-centered neglect may also reflect a difference in the hemisphere involved: it seems that at least the left hemisphere is crucial in order to have an ipsilateral left reading disorder with no clear marks of visuo-spatial neglect (RR, Haywood and Coltheart, 2001; TB, Patterson and Wilson, 1990; JM, Katz and Sevush, 1989 and YM, Cohen and Dehaene, 1991), at least for right-handed patients and for patients without hemianopia (see for different results, Caramazza and Hillis, 1990; Hillis and Caramazza, 1990). RCG, although bilaterally damaged, could be included in the first type of stimulus-centered deficit, having (almost) no signs of unilateral spatial neglect and attentional deficit. In fact, he had a good performance on the bisection and cancellation tasks, failing only on the Wundt-Jastrow Area Illusion test. A possible explanation of the poor performance on the Wundt-Jastrow Area Illusion test is that it may depend on the same mechanism underlying the reading disorder. A study by Cocchini and others (1999) described a patient (AB) suffering from a lesion in the right parietal lobe, who performed very poorly on tasks such as cancellation while his performance on a single word reading task and the Wundt-Jastrow Area Illusion test was normal (the opposite pattern shown by the patient described in the present study). AB also presented extinction. The authors (Cocchini *et al.*, 1999) interpreted these results as being evidence of the presence of neglect without extinction due to a dissociation within a parallel/serial distinction framework. In neglect there is a loss of serial processing strictly related to the right parietal hemisphere whereby extinction reflects a problem in processing the information in parallel. Even if patient RCG did not show visual extinction, we have a double dissociation between standard task of neglect, on the one hand, and single

word reading and Wundt-Jastrow illusion, on the other. Last but not least, there is the possibility that RCG's performance is leading to a unilateral visual recognition deficit, restricted, in free vision, to that part of space which is not represented bilaterally (because of exploratory strategies applied with some kinds of material). Visual agnosia involving one hemifield has been rarely described and then with contradictory results (for a review see Mazzucchi *et al.* 1985). Some of these cases concerned all types of visual stimuli (Charnellet and Carbonnel, 1984), whereas other studies reported a category-specific disorder in visual recognition. Almost all the patients showed a visual field defect with the involvement of the corpus callosum.

RCG had difficulty recognizing simple objects only when these were presented tachistoscopically, while letters and digits were misperceived even in free vision. This difference could be due to a defined automatic scanning of linguistic stimuli or to a visual category specificity, which aggravates the impairment of letters and numbers processing. In particular, the involvement of the corpus callosum would induce a lack of transmission between the right posterior hemisphere and the specific module for alphanumeric visual stimuli, localized in the left posterior hemisphere. Conversely, any visual stimulus which needs a unique retinal representation (defined as parallel processing by Cocchini and collaborators) should be misperceived on the left side: the global form of words and numbers as the W-J illusion. In fact, W-J illusion is an ambiguous and meaningless stimulus and no contextual information can be used for guiding a serial visual analysis.

Finally, the results of these experiments show many analogies with the development of the impairment of NT, the 10-year-old Hebrew speaker described by Friedman and Nachman-Kats (2004). NT had difficulty in reading words and non-words. The absence of a pathological score on cancellation tasks, bisections and drawings on one side and the specificity of a stimulus-centered disorder (as the performance was improved by vertical presentation and compromised by horizontal presentation in both standard and mirror conditions) on the other, define a common pattern of developmental and acquired unilateral reading deficits. Even though RCG and many of the cases here described could be phenomenologically defined as cases of stimulus-centered neglect dyslexia, nevertheless they cannot be explained by the same mechanisms underlying unilateral spatial neglect or by the same anatomical structures.

References

- Albert ML. A simple test of visual neglect. *Neurology* 1973; 23: 658–64.
- Arduino LS, Burani C. Neighborhood effects on pseudoword visual processing in a language with shallow orthography. *Journal of Psycholinguistic Research* 2004; 33: 75–95.
- Arduino LS, Burani C, Vallar G. Lexical effects in left neglect dyslexia: A study in Italian patients. *Cognitive Neuropsychology* 2002; 19: 421–44.
- Arduino LS, Burani C, Vallar G. Reading aloud and lexical decision in neglect patients: A dissociation. *Neuropsychologia* 2003; 41: 877–85.
- Barbut D, Gazzaniga M. Disturbances in conceptual space involving language and speech. *Brain* 1987; 110: 1487–96.
- Basso A, Capitani E. Un test standardizzato per la diagnosi di acalculia. Descrizione e valori normativi. *AP-Rivista di applicazioni Psicologiche* 1979; 1: 551–64.
- Baxter DM, Warrington EK. Neglect dysgraphia. *Journal of Neurology, Neurosurgery and Psychiatry* 1983; 45: 1073–78.
- Bender MB, Furlow LT. Phenomenon of visual extinction in homonymous fields and psychological principles involved. *Archives of Neurology and Psychiatry* 1945; 53: 29–33.
- Bisiach E, Faglioni. Recognition of random shapes by patients with unilateral lesions as a function of complexity, association value and delay. *Cortex* 1974; 10: 101–10.
- Bisiach E, Vallar G. Unilateral neglect in humans. In: F, Boller, J, Grafman, G, Rizzolatti, editors. *Handbook of neuropsychology*. 1. Amsterdam: Elsevier Science, BV, 2000; 459–502.
- Capitani E, Neppi-Modona N, Bisiach E. Verbal response and manual response versions of the Milner Landmark Task: Normative Data. *Cortex* 2000; 35: 593–600.
- Caramazza A, Hillis AE. Spatial representation of words in the brain implied by studies of a unilateral neglect patient. *Nature* 1990; 346: 267–69.
- Charnallet A, Carbonnel S, Pellat J. Right visual hemiagnosia: a single case report. *Cortex* 1988; 24: 347–55.
- Cocchini G, Cubelli R, Della Sala S, Beschin N. Neglect without extinction. *Cortex* 1999; 35: 285–313.
- Cohen L, Dehaene S. Neglect dyslexia for numbers? A case report. *Cognitive Neuropsychology* 1991; 8: 39–58.
- Costello AL, Warrington EK. The dissociation of visuospatial neglect and neglect dyslexia. *Journal of Neurology, Neurosurgery, and Psychiatry* 1987; 50: 1110–116.
- Cubelli R, Pugliese M, Gabellini AS. The effect of space location on neglect depends on the nature of the task. *Journal of Neurology* 1994; 241: 611–14.
- Daini R, Angelelli P, Antonucci G, Cappa S, Vallar G. Exploring the syndrome of spatial unilateral neglect through an illusion of length. *Experimental Brain Research* 2002; 144: 224–37.
- Diller L, Weinberg J. Hemi-Inattention in rehabilitation. The evolution of a rational remediation program. In: EA, Weinstein, RP, Friedland, editors. *Hemi-inattention and hemisphere specialization*. 2 New York: Raven Press, 1977; 62–82.
- Ellis AW, Flude BM, Young AW. Neglect dyslexia and the early visual processing of letters in words and nonwords. *Cognitive Neuropsychology* 1987; 4: 439–64.
- Friedman N, Nachman-Kats I. Developmental neglect dyslexia in hebrew-reading child. *Cortex* 2004; 40: 301–13.
- Granà A, Girelli L, Semenza C. Writing and rewriting numerals: Dissociated processing pathways. *Neurocase* 2004; 9: 308–18.
- Halligan PW, Fink GR, Marshall JC, Vallar G. Spatial cognition: Evidence from visual neglect. *Trends in Cognitive Sciences* 2003; 7: 125–33.
- Haywood M, Coltheart M. Neglect dyslexia and the early stages of visual word recognition. *Neurocase* 2000; 6: 33–44.
- Haywood M, Coltheart M. Neglect dyslexia with a stimulus-centered deficit and without visuospatial neglect. *Cognitive Neuropsychology* 2001; 18: 577–615.
- Hillis AE, Caramazza A. The effects of attentional deficits on reading and spelling. In: A, Caramazza, editor. *Cognitive Neuropsychology and Neurolinguistics. Advances in models of cognitive function and impairment*. UK: Lawrence Erlbaum, 1990.
- Hillis AE, Caramazza A. Deficit to stimulus-centered, letter shape representations in a case of “unilateral neglect”. *Neuropsychologia* 1991; 29: 1223–40.
- Hillis AE, Caramazza A. A framework for interpreting distinct patterns of hemispatial neglect. *Neurocase* 1995a; 1: 189–207.
- Hillis AE, Caramazza A. Spatially specific deficits in processing graphemic representations in reading and writing. *Brain and Language* 1995b; 48: 263–308.
- Hillis AE, Rapp B, Benzig L, Caramazza A. Dissociable coordinate frames of unilateral neglect: “Viewer-centered” neglect. *Brain and Cognition* 1998; 37: 491–526.

- Istituto di Linguistica Computazionale, CNR, Pisa, Corpus di Italiano contemporaneo. Unpublished manuscript, 1989.
- Katz RB, Sevush S. Positional dyslexia. *Brain and Language* 1989; 37: 266–89.
- Kinsbourne M, Warrington EK. A variety of reading disability associated with right hemisphere lesions. *Journal of Neurology, Neurosurgery, and Psychiatry* 1962; 25: 339–44.
- Làdavas E, Umiltà C, Mapelli D. Lexical and semantic processing in the absence of word reading: Evidence from neglect dyslexia. *Neuropsychologia* 1997; 35: 1075–85.
- Massironi M, Antonucci G, Pizzamiglio L, Vitale MV, Zoccolotti PL. The Wundt-Jastrow illusion in the study of spatial hemi-inattention. *Neuropsychologia* 1988; 26: 161–66.
- Mazzucchi A, Posteraro L, Nuzzi G, Parma M. Unilateral visual agnosia. *Cortex* 1985; 21: 309–16.
- Miceli G, Capasso R. Masson , editor. I disturbi del calcolo. Diagnosi e Riabilitazione. Masson(editor). , 1991.
- Miceli G, Capasso R. Word-centred neglect dyslexia: Evidence from a new case. *Neurocase* 2001; 7: 221–37.
- Patterson K, Wilson B. A ROSE is a ROSE or a NOSE: A deficit in initial letter identification. *Cognitive Neuropsychology* 1990; 7: 447–77.
- Pizzamiglio L, Judica A, Razzano C, Zoccolotti P. Toward a comprehensive diagnosis of visual-spatial disorders in unilateral brain damaged patients. *Psychological Assessment*, 1989; 5: 199–218.
- Rapp B, Caramazza A. Spatially determined deficits in letter and word processing. *Cognitive Neuropsychology* 1991; 8: 275–311.
- Riddoch J, Humphreys GW. . Birmingham Object Recognition Battery (BORB). Lawrence Erlbaum: UK, 1993.
- Riddoch J, Humphreys GW, Cleton P, Fery P. Interaction of attentional and lexical processes in neglect dyslexia. *Cognitive Neuropsychology* 1990; 7: 479–517.
- Subbiah I, Caramazza A. Stimulus-centered neglect in reading and object recognition. *Neurocase* 2000; 6: 13–31.
- Vallar G. Spatial hemineglect in humans. *Trends in cognitive sciences*. Suffolk, UK: Thames Valley Test Company, 1998; 87–97.
- Vallar G, Daini R, Antonucci G. Processing of illusion of length in spatial hemineglect. A study on line bisection. *Neuropsychologia*. 2000; 38: 1087–97.
- Vallar G, Guariglia C, Nico D, Tabossi P. Left neglect dyslexia and the processing of neglected information. *Journal of Clinical and Experimental Neuropsychology* 1996; 18: 1–14.
- Vallar G, Rusconi ML, Fontana S, Musicco M. Tre test di esplorazione visuo-spaziale: taratura su 212 soggetti normali. *Archivio di Psicologia, Neurologia e Psichiatria* 1994; 55: 827–41.
- Warrington EK, James M. Visual Object and Space Perceptual Battery (VOSP). Suffolk, UK: Thames Valley Test Company, 1991.
- Wilson B, Cockburn J, Halligan P. Development of a behavioral test of visuospatial neglect. *Archives of Physical Medicine and Rehabilitation* 1987; 68: 98–102.
- Young AW, Newcombe F, Ellis AW. Different impairments contribute to Neglect Dyslexia. *Cognitive Neuropsychology* 1991; 8: 177–91.
- Zoccolotti P, Antonucci G, Judica A, Montenero P, Pizzamiglio L, Razzano C. Incidence and evolution of the hemi-neglect disorder in chronic patients with unilateral right brain-damage. *International Journal of Neuroscience* 1989; 47: 209–16.