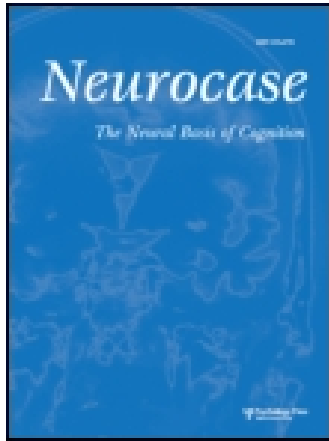


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Left Ipsilesional Neglect for Visual Imagery: A Mental Image Generation Impairment?

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In this article, we describe a patient, CN, with unilateral left posterior brain damage, who shows a rare occurrence of left ipsilesional neglect limited to mental representations. CN's clinical pattern is consistent with the hypothesis that different mechanisms underlie perceptual and representational neglect. We also discuss an interpretation of representational neglect based on the different involvement of the two hemispheres in visual imagery processes. In particular, left brain lesions do not present the typical strong contralesional bias and may lead to an impairment of mental generation of either side of the image, depending on pre-morbid and methodological factors.

Introduction

Patients suffering from unilateral neglect may fail to report, respond to, or orient toward stimuli presented in the hemispace contralateral to the brain lesion (contralesional neglect). This syndrome is usually more frequent, severe, and long-lasting after right brain damage, resulting in left neglect (Robertson and Halligan, 1999). Unilateral neglect is a complex and multifactorial syndrome and the spectrum of different disorders can all dissociate from each other. However, theoretical accounts tend to interpret it as a unitary phenomenon despite evidence of clear dissociations between different forms of neglect (e.g., Halligan and Marshall, 1992) and in particular between perceptual and representational domains.

Since Bisiach and Luzzatti's (1978; see also previous studies e.g., Denny-Brown *et al.*, 1952 and Welman, 1969) demonstration that neglect can be observed, not only in the perceptual domain, but also at a representational level, these two forms of neglect have been considered co-occurrent and mediated by similar underlying mechanisms (e.g., Halsband *et al.*, 1985; Meador *et al.*, 1987; Geminiani and Bottini, 1992). However, perceptual neglect not associated with representational neglect is quite common. For example, Bartolomeo *et al.* (1994) found 12 out of 30 (40%) right brain damaged patients showing perceptual but not representational neglect. These authors also observed that only one patient showed neglect limited to representational neglect in the chronic phase after recovery of a

previous perceptual form. This finding led the authors to conclude that these two forms of neglect depend on the same cognitive processes and that the isolated occurrence of representational neglect may result from a different recovery rate between perceptual and representational deficits (see also Bartolomeo, 2002). However, a few patients showing neglect limited to mental images not associated with a previous perceptual form have been also described (Guariglia *et al.*, 1993; Beschin *et al.*, 1997; Coslett, 1997) suggesting that different mechanisms underlie these two forms of neglect. In particular, Beschin *et al.*, (2000) described a patient, suffering from a left parieto-occipital haemorrhage and a right thalamic stroke, who showed left representational neglect and right perceptual neglect.

Therefore, the hypothesis of possible dissociation between different forms of neglect is still very much a matter for debate.

A second important issue related to the neglect literature is hemispheric laterality. Neglect is usually observed following damage of the right hemisphere and it typically affects the contralesional (left) side of the field or image, suggesting a main role of right brain areas in directing attention towards the opposite side (e.g., Heilman *et al.*, 1987). However, a growing number of studies have reported evidence of ipsilesional (also called "paradoxical") right neglect (e.g., Halligan *et al.*, 1991; Robertson *et al.*, 1994; Kim *et al.*, 1999; Choi *et al.*, 2001), leading to a reconsideration of theoretical interpretations. Furthermore, as with perceptual neglect, representational neglect has been strongly linked to brain lesions of the right hemisphere resulting in left-sided neglect (e.g., Bartolomeo *et al.*, 1994). Moreover, while cases of right neglect due to left brain damage (e.g., Stone *et al.*, 1993) or bilateral lesions (e.g., Weintraub *et al.*, 1996) have been occasionally described, no evidence, to our knowledge, of a similar phenomenon in the representational domain has been reported in the literature. Therefore, some authors have suggested that the attentional stages of mental representation may be subsuming networks even more lateralized to the right hemisphere than those involved in the perceptual form of neglect (Beschin

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et al., 2000). However, the strong relationship between right hemisphere and representational neglect may be only apparent and relies on a general lack of assessment of this aspect among left brain damaged patients. This may be due to a number of reasons, including the fact that typical representational tasks (such as description of geographical or familiar places) heavily rely upon patient's verbal competences and so are not easily accessible for aphasic patients. As a result, only a few studies have systematically investigated this syndrome with left brain damaged patients (e.g., Stone *et al.*, 1993; Bartolomeo *et al.*, 1994) and in some studies (e.g., Bartolomeo *et al.*, 1994) the doubt that a lack of evidence may be due to a floor effect is still matter of debate.

In contrast, some authors (e.g., Kosslyn, 1987) have suggested that cognitive processes related to mental representations rely on both right and left hemispheres, and one of the reasons for suspecting a more crucial role of the left hemisphere in representational neglect is the well-documented involvement of this hemisphere during the earlier stages of visual imagery (e.g., Farah, 2000). Farah (1984; see also Kosslyn, 1994) proposed a multicomponent model consisting of a visual buffer which receives "bottom-up" information from visual percepts through the encoding process, and "top-down" information from long term memory in order to generate internal images. Damage to the encoding process should result in impaired processing of new information coming from visual input but spared imagery. On the other hand, isolated imagery deficits will result from damage to the generation process. Interestingly, posterior areas of the left hemisphere have been associated with the generating process (e.g., Farah *et al.*, 1988) while the spatial organization of this information in a visual buffer might be accomplished by the right hemisphere (e.g., Kosslyn, 1987). Defective exploration (scanning) of this spatially organised information may result in a neglect syndrome (e.g., Ellis *et al.*, 1996). However, within this theoretical framework, it remains unclear why neglect can also be observed following lesions of the left hemisphere (e.g., Cubelli *et al.*, 1991) and, even more challenging, how evidence of ipsilesional (both right and left) neglect can be accounted for (e.g., Robertson *et al.*, 1994; Riddoch *et al.*, 1995).

In this context, representational neglect following left brain damage is interesting as an opportunity to look into the possible relationship between a specific form of neglect and visual imagery processes.

In this article we report the rare occurrence of a left-brain damaged patient (CN) showing ipsilesional neglect limited to the representational domain.

Case Report

CN¹ is a 79-year-old man with 5 years of formal education (normal education level for Italians of this age). He is right-

handed (Oldfield's score = 70%; cut-off = 50%; Oldfield, 1971). In September 2001 he suffered from an ischemic stroke and a CT scan performed in the acute phase showed a left posterior brain lesion in the territory of the posterior cerebral artery. The clinical picture in the acute phase was characterized by a clear left hemisphere syndrome: he showed right side weakness associated with right hemianopia, letter by letter reading with a few anomic errors and defective long-term verbal memory. Although neglect was not directly investigated in the acute phase, no clinical evidence of perceptual neglect was reported in his medical record and no sign of perceptual neglect was observed in reading and writing ten words and in copying eight geometrical drawings. When his son was questioned about CN's difficulties in everyday life, he did not mention deficits that may suggest a possible neglect syndrome.

In September 2002, one year after the stroke, he came to our attention as he agreed to participate in an experimental study. Consent for testing was obtained from CN and his family. Examination was continued until a second stroke occurred about 10 months later.

Neuroimaging Examination

An MRI scan of the brain confirmed a single left occipitotemporal hemisphere lesion (see Figure 1a). He also underwent a SPECT investigation that revealed hypoperfusion of the left posterior area (see Figure 1b).

Neuropsychological Examination

CN appeared oriented in space and time and cooperative. Performance on a range of neuropsychological tests is reported in Table 1. His performance on the Mini Mental State Examination (Measso *et al.*, 1993) was adequate for his socio-educational background. He did not show deficits on verbal short-term memory (Orsini *et al.*, 1987), apraxia (De Renzi *et al.*, 1980) and he did not show signs of acalculia (Basso and Capitani, 1979). Also, his verbal reasoning ability (Spinnler and Tognoni, 1987), and verbal comprehension (Spinnler and Tognoni, 1987) were preserved and he performed above cut-off in a verbal fluency task (Lusetti, 2001). However, he showed a mild impairment on a spatial short-term memory task (Spinnler and Tognoni, 1987), and he performed very poorly on a verbal long term memory task (De Renzi *et al.*, 1977), on semantic fluency (Lusetti, 2001) and on naming tasks (De Renzi *et al.*, 1987), whereas his performance was just below cut-off when asked to perform a cognitive estimation task (Nichelli *et al.*, 2002). On the visual search test (Spinnler and Tognoni, 1987), a test to assess selective attention, patients are asked to identify specific digits in a complex matrix containing several other numbers (distractors), within 45 seconds. His performance on this test was very poor; however, the low score was not due to perceptual neglect. Indeed, regardless of the time limit on the test,

¹ CN's preliminary data have been presented at the Annual Congress 21th European Workshop on Cognitive Neuropsychology in Bressanone (Proceedings in Cortex 2004: 40).

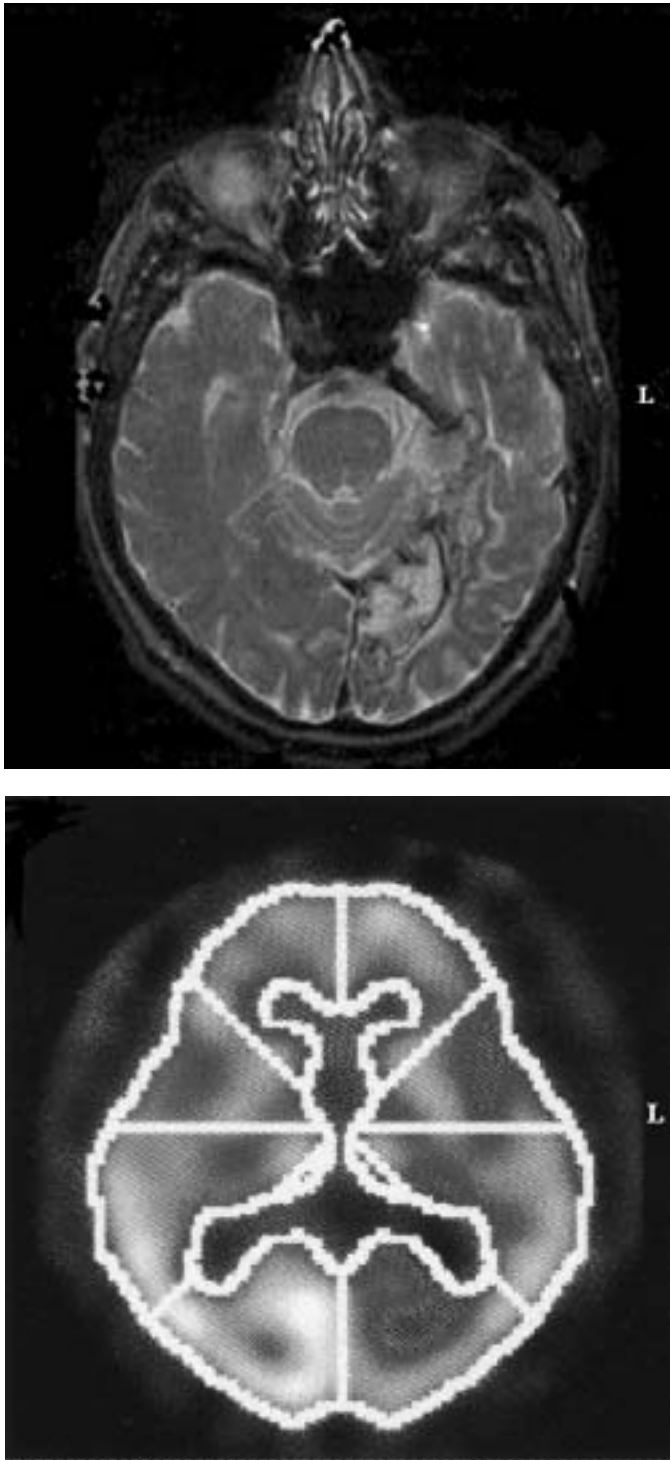


Fig. 1. CN's MRI scan (a) and SPECT scan (b). Radiological convention.

he omitted 5 out of 32 (16%) digits on the left and 5 out of 28 (18%) on the right side of the matrix.

On a visual extinction task, CN could not detect single unilateral stimuli because of his right hemianopsia. He did not

Table 1. CN's general neuropsychological examination scores adjusted for age, education and, whenever appropriate, gender

Test (range)	CN's adjusted scores	Cut-off
Global assessment		
Mini Mental State Examination (0–30)	25.03	24
Language		
Naming (0–60)	42	55
Token test (0–36)	28	26.5
Memory		
Digit span (0–inf.)	4.5	3.5 with 3.75
Visuo-spatial span (0–inf.)	3.5	3.5
Prose memory (0–16)	1	15.76
Semantic fluency (0–inf)	33.6	34.5
Executive functions		
Phonemic fluency (0–inf.)	28.8	18.7
Verbal reasoning (0–60)	42.5	32
Cognitive estimation (0–60)	38[^]	40
Apraxia		
Ideomotor (0–72)	21	20
Bucco-facial (0–24)	68	62
Constructive (0–20)	16	14
Attention		
Visual search test (0–60)	19,5	31
Acalculia		
Digit comparison (0–12)	12 [^]	—
Additions (0–7)	7 [^]	—
Subtractions (0–7)	7 [^]	—

Pathological scores in bold.

[^]Score not adjusted for age, education and gender.

show auditory or tactile extinction on confrontation tasks (Bisiach *et al.*, 1984; Moscovitch and Behrmann, 1994).

Personal Neglect

Personal neglect was assessed by means of three standardized tests (the One Item test, the Comb/Razor test and the Fluff test). The results are reported in Table 2.

On the One Item test (Bisiach *et al.*, 1986; 1990) the patient lies with his upper limbs positioned at the side of his/her trunk and is asked to touch one hand (usually the contralesional one) with the other. A score from 0 (prompt reaching of the hand, i.e., no personal neglect) to 3 (no movement towards the target hand, i.e., severe personal neglect) is given. CN performed the task twice using one hand at a time. On both occasions he promptly reached the other hand showing no evidence of personal neglect.

On the Comb and Razor test (Beschin and Robertson, 1997), he was asked to pretend to comb and shave himself for 30 seconds continuously. Total number of strokes for each side is compared and evidence of neglect consists of a performance discrepancy between the two sides over a specific

Table 2. CN's performance on tasks assessing personal and extrapersonal neglect

Test (range)	CN's scores			Cut-off
Personal neglect				
One item test				
– right hand (0–3)	0 = no evidence of neglect			
– left hand (0–3)	0 = no evidence of neglect			
Fluff test				
	L%	R%		
– right hand (0–100)	67	67		87%
– left hand (0–100)	100	93		87%
Comb and Razor#				
– left hand (+1 / –1)		0.34		<0.35
– right hand (+1 / –1)		0.22		<0.35
Extrapersonal neglect				
	L	R	R-L	R-L
Line cancellation (L = 0–20; R = 0–20)	20	20	0	<1
Star cancellation (L = 0–27; R = 0–27)	27	27	0	<2
Naming objects on the table (L = 0–5; R = 0–5)	5	5	—	—
	CN's scores			
Copying drawings (0–7)	7			
Copying Rey Figure B (0–11)	11			
Reading sentences (0–5)	5			
Line Bisection (+107mm /–107 mm)	mean = –.02#; sd = .54 (no evidence of neglect)			

Note. L = left; R = right.

Pathological scores in bold (i.e., below cut-off).

^Scores are below cut-off however no left-right asymmetry has been shown.

positive scores indicate leftward errors.

cut-off. He performed the Comb and Razor test twice, first using his left hand and then his right hand. In both cases he did not show evidence of left or right personal neglect.

Finally, CN performed the Fluff test (Cocchini *et al.*, 2001). On this test patients are blindfolded and then asked to detach targets previously attached on their body (i.e., arms, legs and trunk) using only one hand (usually the contralesional one). The percentage of stickers detached from each side is measured and compared with a cut-off. CN performed the test twice, first using his left hand and then using his right hand. He performed above cut-off using his left hand. Also, when he used his right hand he did not show right-left asymmetry, despite the equally poor performance (i.e., below cut-off) on both sides of the body due to his motor impairment.

Extrapersonal Perceptual Neglect Assessment

Table 2 also shows CN's results on a series of tests assessing extrapersonal neglect. He performed at ceiling (100%) on Line (Albert, 1973) and Star (Wilson *et al.*, 1987) cancellation tests. He did not show perceptual neglect when asked to copy a picture of two separated daisies (Marshall and Halligan, 1993) and six geometrical drawings taken from Arrigoni and De Renzi's (1964) constructional apraxia test (see Figure 2). He read five sentences (a total of 43 words) without flaw and he also showed no signs of neglect when he copied the Rey Figure B (1959). When asked to indicate the midpoint of nine horizontal lines of different lengths and displayed in different

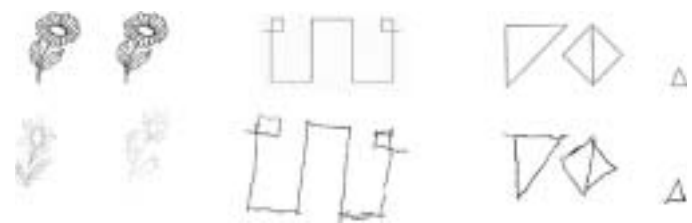


Fig. 2. CN's copy of drawings. Original drawings are shown above CN's copy.

locations on the sheet, he was very accurate making only a minimal error towards the left, which is in line with healthy volunteers' performance (Bradshaw *et al.*, 1985).

Finally, when walking (with an aid) CN never bumped into obstacles or changed trajectory at the last moment, suggesting that he did not neglect information located in the far left or right of space.

In summary, we found no evidence of perceptual extrapersonal or personal neglect on psychometric evaluation or in everyday life.

Representational Neglect

Representational neglect was assessed by means of the following tasks.

Drawing from Memory. On six different occasions, CN was asked to draw a clock from memory. An eight cm diameter circle was drawn in the center of an A4 sheet. CN was asked to add digits and hands from memory. We considered the total number of digits correctly drawn on the correct side (i.e., left or right). Omission errors were considered evidence of neglect (Berti *et al.*, 1996). Data, reported in Table 3, indicate signs of left (i.e., ipsilesional) neglect in all drawings. In Figure 3, we provide two examples of the six clocks. Note that neglect is evident across the patient's different clock styles (see Halligan and Marshall, 1994 for a discussion of a similar phenomenon). On one occasion, CN was questioned about a clock (Figure 3b) that he had finished drawing a few minutes before. He looked at it and said with surprise "No, this part is missing", indicating the left side of the clock. Invited to complete the clock, he started counting the hours he had already drawn but, after having said a few numbers he reconsidered his previous observation, stating that the drawing was complete.

CN's drawing from memory was very poor: for example he drew only three confused lines to represent a person profile, a small square for a house and two confused rectangles for the Rey Figure B previously displayed for 3 minutes (contrary to his good copy—see "extrapersonal perceptual neglect assessment" section). We presented him with four incomplete drawings taken from Snodgrass and Vanderwaart (1980). A bicycle (without the two wheels), a bunch of grapes (where only 11 grapes in the middle were left), a sunflower (missing all the right and left petals at the top and a large half leaf on the left), and a daisy (missing all the right and left petals at the top and three leaves on each side) were displayed in the center of a A4 sheet and CN was asked to complete the drawings. He completed the bicycle by adding the two missing wheels. However, he drew only a few grapes on the right side, he missed a few petals and the remaining half part of the left leaf of the sunflower (see Figure 3c), and he did not complete the petals on the left and missed one small right leaf on the daisy. Note that for the sunflower and the daisy, the

Table 3. CN's performance on three tasks to assess evidence of representational neglect

Clock drawings	Correct side*			
	L (0–5)	R (0–5)		
Clock 1 (see also Figure 3a)	2	5		
Clock 2 (see also Figure 3b)	0	4**		
Clock 3	3	5		
Clock 4	0	5		
Clock 5	4	5		
Clock 6	3	5		
Complex scene description	CN [#]		Control group ^{##}	
	L	R	L	R
Immediate recall –15 sec.	2 (27%)	3 (75%)	7.3 (sd = 2.3)	4 (sd = 0)
Delayed recall – 5 min.	3 (41%)	3 (75%)	7.3 (sd = 1.5)	4 (sd = 0)
Perceptual task	8 (100%)	3 (75%)	8.0 (sd = 1.0)	4 (sd = 0)
Clock hands position task	Hand positions			
	Both L (0–12)	L & R (0–18)	Both R (0–12)	
CN's response accuracy				
Both L	1 (8%)	1 (5%)	0	
L & R	8 (67%)	7 (39%)	0	
Both R	3 (25%)	10 (55%)	12 (100%)	
CN's response latencies				
Mean (sd) session II	13.7 (3.0)	18.0 (5.8)	8.25 (2.4)	
Mean (sd) session III	24.0 (14.9)	30.0 (15.6)	18.5 (9.5)	
Mean (sd) total	18.9 (11.4)	24.0 (13.8)	13.4 (8.4)	

Note. L = left; R = right.

*Number of digits located in the correct side (i.e., left or right). Digits/positions corresponding to the hours "12" and "6" have not been considered.

**Digit "1" was not considered as it was placed on the number "12" position.

[#]Number of details reported for each side. Percentage are calculated considering controls' means on the same condition.

^{##}Mean and standard deviation (in brackets) of total number of details identified within 3 minutes by three healthy elderly volunteers (mean age = 67.0; SD = 4.6).

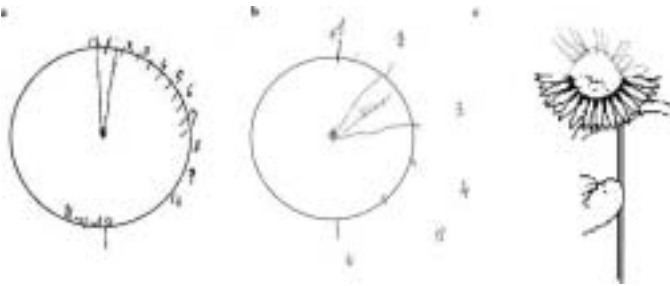


Fig. 3. CN's drawings from memory. a-b) Two samples of CN's clocks drawn from memory. c) An example (sunflower) of CN's completion of drawings.

details missed were integral parts of the stimulus (e.g., half-leaf and petals).

Complex Scene Description. CN was asked to describe from memory the "Cookie Theft" picture taken from the Boston Naming Test (Goodglass and Kaplan, 1972) and previously displayed for 3 minutes. Since the original version of the picture displays more details on its right side, to challenge his "neglected" side of the mental image, we displayed a mirror version of the picture. CN was able to correctly report the majority of the details of the picture. Due to his naming difficulties, we considered validly reported details that he clearly described by circumlocutions and *passé-partout* words (i.e., "that thing ... rounded ... on woman's hands" meaning the plate). All details for final counting were considered as in previous procedure by Beschin *et al.* (1997). Data are reported in Table 3. Compared to the control group, on both immediate (i.e., after 15 seconds) and delayed (i.e., after 5 minutes) recall tasks, CN reported a considerable lower percentage of left (27% and 41%, respectively) than right (75% for both memory conditions) details. However, when asked once again to describe the same picture while it was on view (perceptual task), CN reported (in 3 minutes) more details on the left (100%) than the right (75%).

We also tested CN's ability to describe from memory scenes encoded before the brain damage. He did not report any detail of the map of Italy and of a familiar town square. Also, he provided a confused description of his house with no clear spatial location of the rooms.

Clock Hands Position Task. CN was given a modified version of the clock task by Grossi *et al.* (1989). He was asked to state on which side (left or right) the hands of an imagined clock were displayed at a given time. There were 14 items: four times both hands were on the right side (e.g., 2:20); four times they were both on the left side (e.g., 8:45) and six times one hand was on the right and the other on the left side (e.g., 8:10). The test was given on three different occasions on different days, for a total of 42 items. To avoid a possible counting strategy, on each occasion four stimuli were read in a

different format. For example, 9:45 was literally read as "a quarter to ten" and 2:15 was read as "a quarter past two".

As shown in Table 3, he performed flawlessly (100%) when both the hands were on the right side. However, his accuracy decreased considerably when one or both hands were on the left side. He consistently stated the wrong side for left hands (22 times) and only once for a right hand. This may suggest that his responses were the result of perseveration for "right" responses. However, during the entire examination, he never showed perseveration in any other task. Moreover, response latencies collected during the last two sessions suggest that he was performing some imagery search before responding (see Table 3).

Mental Number Line Bisection (Zorzi *et al.*, 2002). On this task participants are presented with numbers. They hear two digits that define a number interval and then they are requested to state, without counting, the midpoint number. For example, the midpoint number of the interval 4–10 is 7. Misplacements toward left or toward right of the midpoint are considered evidence of right or left representational neglect, respectively. Interval sizes varied from three (e.g., 10–12), five, seven or nine (e.g., 10–18) numbers. For half of the trials the intervals were read in ascending order (e.g., 21–25) and for the other half they were read in descending order (e.g., 25–21). A total of 64 trials were given, 16 for each interval. CN's error percentage (56.9%) was considerably higher than controls' means (1.3% for healthy volunteers and 10.9% for patients not showing signs of neglect—see Zorzi *et al.*, 2002, for controls' data with very similar stimuli). Moreover, while the controls' mean error was slightly towards the left, CN's showed a high rightward shift of the midpoint for each interval (see Figure 4), showing clear left neglect.

In conclusion, CN consistently showed evidence of left representational neglect when he was asked to draw from memory, to complete some drawings, to describe a complex picture from memory, to state clock hand positions or the midpoint of a mental number line. Note that he never showed any sign of awareness related to this specific difficulty.

Visual Imagery

In the previous examination, CN showed some general difficulty in carrying out visual imagery tasks, such as describing familiar squares or geographical places. To investigate his general mental imagery ability, he was asked to state which of two objects, animals or vegetables, was the largest (Farah *et al.*, 1988). The examiner read aloud the two nouns. There were fifteen pairs (five for each category). In Farah *et al.*'s study a group of 12 healthy volunteers performed this type of task with very few errors and three healthy Italian volunteers (see their demographical details on Table 3) performed the Italian version flawlessly. CN made two errors, suggesting that his visual imagery ability was not dramatically impaired.

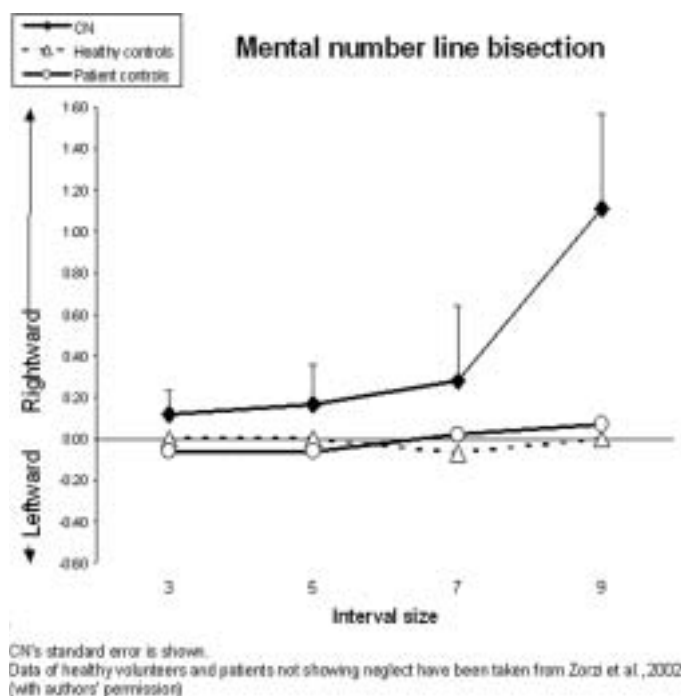


Fig. 4. CN's mean deviation on the mental number line bisection test.

Discussion

CN showed left (ipsilesional) neglect limited to the representational domain while no evidence of right (contralesional) neglect was observed in any perceptual or mental representational task. This clinical picture was consistently found across several tests carried out on different occasions, excluding a sporadic result due to random fluctuations in attention. The site of his lesion (left) is not only supported by the clinical manifestations of cognitive (e.g., language), sensory (right hemianopsia) and motor disorders (right limb weakness), but also by neuroimaging investigation, where the brain damage was limited to the left hemisphere. Hence, CN's case appears to be an unyielding combination of two quite rare occurrences: the dissociation between perceptual and representational domains and the occurrence of ipsilesional neglect.

Neglect limited to the representational domain has occasionally been described (Guariglia *et al.*, 1993; Coslett, 1997; Beschin *et al.*, 1997; Beschin *et al.*, 2000) however, Bartolomeo *et al.* (1994; see also Bartolomeo, 2002) suggested that this dissociation can result from an early recovery of perceptual neglect. CN's neglect was not directly investigated in the acute phase and no definitive conclusion about a possible recovery can be drawn; however, immediately after the vascular accident, he underwent a detailed psychometric assessment to investigate visual perception, memory and language. Had CN suffered from a perceptual neglect in the acute phase, evidence of it would hardly have gone unnoticed

during the neuropsychological assessment. Also the hypothesis that a form of attentional compensation towards the hemianopic field may have hidden a latent contralesional perceptual neglect seems quite unlikely, since no evidence of perceptual neglect was observed in the acute phase (i.e., before the compensation may actually occur), and no signs of ipsilesional neglect were ever observed, as would be expected in the case of attentional bias towards one side (Robertson *et al.*, 1994). Therefore, we believe that there is reasonable doubt that CN's actual dissociation resulted from the recovery of a perceptual form of which we did not find any evidence. Moreover, Bartolomeo *et al.*'s (1994) interpretation also fails to account for the patient described by Beschin *et al.* (2000), who showed a double dissociation between perceptual and representational neglect. Indeed, following bilateral brain lesions, Beschin *et al.*'s patient (Piazza) showed right perceptual neglect and left representational neglect, providing strong evidence against the hypothesis that neglect is a unitary entity. Therefore, in line with other clinical cases in the literature (Guariglia *et al.*, 1993; Coslett, 1997; Beschin *et al.*, 1997; Beschin *et al.*, 2000) CN contributes to the growing idea that perceptual and representational domains can be selectively impaired. However, in contrast with the previous studies, CN's neglect is ipsilesional.

The laterality issue represents the second crucial aspect of CN. Except for the ipsilesional neglect for mental images, he is showing motor and cognitive symptoms entirely in line with the left brain lesion documented by means of CT, MRI scans and SPECT examination.

Even if ipsilesional neglect is not a frequent occurrence, it has been occasionally described in the literature. A few authors have described ipsilesional neglect following unilateral right brain damage (Halligan *et al.*, 1991; Robertson *et al.*, 1994; Kim *et al.*, 1999; Choi *et al.*, 2001). Halligan *et al.* (1991) found that 24 out of 90 (27%) right brain damaged patients were showing at least 5% more omissions on the ipsilesional side than on the contralesional one. Left ipsilesional neglect has also been observed. Welman (1969) described two left brain damaged patients (cases 2 and 4) showing neglect limited to the ipsilesional side for perceptual and representational domains. Other studies reported left brain damaged patients showing ipsilesional neglect only for verbal material (dyslexia) in association (Katz and Sevush, 1989—case 1; Cubelli *et al.*, 1991) or not (Katz and Sevush, 1989—case 2; Haywood and Coltheart, 2001) with contralesional neglect for non-verbal material. Kashiwagi *et al.* (1990) reported a similar association of contralesional and ipsilesional neglect in a patient (YY) with brain damage on left hemisphere and on corpus callosum. YY neglected the left side of the space when he used the right hand but he showed right neglect when he used the left hand. This suggests that the left hemisphere may play a crucial role in neglect assessment when verbal tasks or right hand performance are requested. In line with these findings, previous authors have described patients showing left ipsilesional neglect limited to the use of the right hand (Sine *et al.*, 1984;

Goldenberg, 1986). A possible interpretation would suggest that activation of the left dominant hemisphere enhances an attentional right-orienting tendency of the left hemisphere, producing a stronger orientation of attention toward the right and resulting in left neglect for verbal tasks and motor tasks performed with the right hand. However, this interpretation does not fully account for CN's results since he showed left representational neglect on non-verbal tasks (e.g., clock drawings) and on tasks where no motor responses were required (e.g., clock hand position test or mental number line test). Moreover, if the left activation hypothesis accounted for the evidence of neglect, we would have observed signs of perceptual and personal neglect in all those tests requiring verbal descriptions (i.e., word reading, description of the complex scene on view) or right-handed motor responses (i.e., cancellation tasks, copying of drawings, line bisection, personal neglect tests). This was not the case. Finally, the left activation hypothesis does not account for other cases described in the literature. For example, Humphreys and Riddoch (1994; see also Riddoch *et al.*, 1995) described two patients with unilateral left lesion (case EL) and bilateral lesions (case JR) showing contralesional and ipsilesional neglect on different tasks regardless of the nature of the stimuli (verbal or spatial) and the hand used. These authors claimed that the side that is neglected mainly depends on "the nature of the representation mediating task performance" (p. 231). In other words, it depends on whether the patient is required to represent stimuli as parts of a whole object (such as cancelling lines uniformly distributed in a whole page) or as separate perceptual objects (such as cancelling lines framed in two separate blocks). The authors suggested that a lesion of the left hemisphere (as for our patient) should result in right neglect for stimuli represented as parts of a whole object (e.g., line cancellation, drawing, oral spelling) and in a possible left neglect as having difficulty in focusing attention on the parts of objects (e.g., word reading or line cancellation in framed strips). However, CN did not show right or left perceptual neglect in several tests that may encompass both types of object representations (e.g., his performance was at ceiling on all cancellation tests and on drawings of two separated daisies). More important, contrary to the predictions of the object representation hypothesis, CN did show *left*, rather than right, neglect on a number of tasks where stimuli were represented as parts of a whole (i.e., drawings from memory, clock hand position test, mental number line test, complex scene description).

An alternative explanation for ipsilesional neglect has been put forward by Robertson *et al.* (1994; see also Pierson-Savage *et al.*, 1988) who suggested that this form of neglect may be the result of a compensatory scanning strategy in association with a non-lateralized attentional deficit.

We cannot exclude the possibility that CN is showing non-lateralized attentional disorder, as his poor performance on the Visual Search test seems to imply. It may be possible that CN's ipsilesional representational neglect could be the result of an "overcompensatory" rightward attentional mechanism,

which allows him to attend flawlessly to those stimuli located on the contralesional side (which is supposed to be the real neglected side) of the image at the expense of the ipsilesional side. However, the compensatory mechanism relies on a feedback system (Robertson and Halligan, 1999) and this implies that CN should have shown quite severe right neglect, at least during the acute phase, in order to "trigger" the compensatory mechanisms. We have already discussed the possibility of right neglect as very unlikely and not supported by any data. Moreover, the compensatory explanation for ipsilesional neglect does not account for other studies in the literature. Kim *et al.* (1999) described five right brain damaged patients showing ipsilesional neglect; at least two of them (patients 3 and 4) showed no contralesional neglect and they were first assessed in a very early stage of illness (i.e., patient 3 after two weeks and patient 4 after only 3 days). Finally, the compensatory hypothesis also fails to account for those patients whose neglected side shifted according to the type of task (e.g., Costello and Warrington's (1987) and hand used (Sine *et al.*, 1984; Goldenberg, 1986; Kashiwagi *et al.*, 1990).

Since CN's neglect is limited to visual images, a further possible alternative explanation should consider the theoretical framework of visual imagery. Exploration and manipulation of mental visual images resemble exploration and manipulation of visual percepts, although in perception, image generation plays no role (e.g., Goldenberg, 1993). Generating mental images is attributed to the left hemisphere (Farah, 1984; Farah *et al.*, 1988) while the right hemisphere organises images according to spatial coordinates and explores them (Kosslyn, 1987). Therefore, while the manipulation and maintenance of a conscious image requires attentionally based operations (Pearson *et al.*, 2001), image generation is a sequential multi-stage process in which information is retrieved from long-term memory and then "properly positioned" to form a consciously experienced short-term mental image (Farah *et al.*, 1988; Kosslyn, 1994). Considering Farah's model (1984), CN's neglect for the ipsilesional side of mental images cannot be accounted for by a bottom-up deficit in encoding visual input; indeed he did not show perceptual neglect at the time of the investigation, and several tasks used to assess representational neglect (i.e., drawings from memory, clock hand position test, mental number line test) required him to retrieve information stored in long term memory in a pre-morbid phase. Some authors have suggested that this form of neglect reflects impairment in the scanning or maintenance of the left side of the mental image (e.g., Guariglia *et al.*, 1993; Ellis *et al.*, 1996). This may be a possible explanation for CN's neglect; however, scanning processes have been attributed to the right hemisphere (e.g., Kosslyn, 1987), whereas CN's brain lesion was limited to the left hemisphere. Therefore, in order to maintain this interpretation we should also assume that the pre-morbid role of CN's left hemisphere, rather than the right hemisphere, was to attend to (or explore) mental

images. Even if this *ad hoc* hypothesis remains a possible and reasonable explanation of CN's results, the issue of falsification and the specific locus of CN's brain lesion lead us to consider a possible alternative explanation. Indeed CN's brain lesion is located in the left temporo-occipital lobe and several studies have demonstrated that this area is involved in top-down processes that retrieve information from long term memory and generate the mental image (e.g., D'Esposito *et al.*, 1997). An interesting study on brain asymmetries in image generation demonstrated that when healthy volunteers are asked to image one half of an object, most of them tend to image the right side of it (Shuren *et al.*, 1996). Therefore, it is possible that CN's representational ipsilesional neglect is linked to a selective impairment of the mental image generation process, which resulted in an exacerbation of the pre-morbid tendency. Cubelli *et al.* (1991) suggested that impairment at different levels of representation may lead to different manifestations of neglect syndrome (see also Caramazza and Hillis, 1990; Humphreys and Riddoch, 1994). Similarly, we suggest that representational neglect may occur at different stages of the imagery process leading to different manifestations of neglect syndrome. This hypothesis has strong implications, which may be disproved by future investigations. In particular, it implies that a different manifestation of representational neglect might occur following right or left brain damage. As suggested by some authors (e.g., Ellis *et al.*, 1996), a right brain lesion would impair spatial scanning (exploration) of mental images already generated. In this case, the deficit may be better explained as an attentional disorder and, as a consequence of the well documented asymmetry of frequency between left and right space neglect, would result in a contralesional (more often left) representational neglect. In contrast, representational neglect following left posterior brain damage might represent an impaired mental image generation with no strong contralesional bias of attention. Therefore, the side neglected may depend on the type of task (Costello and Warrington, 1987; Katz and Sevush, 1989; Cubelli *et al.*, 1991; Humphreys and Riddoch, 1994; Haywood and Coltheart, 2001), hand used (Sine *et al.*, 1984; Goldenberg, 1986; Kashiwagi *et al.*, 1990) or, as may be in CN's case, the general exacerbation of a pre-morbid tendency to image the right side of pictures (Shuren *et al.*, 1996). Considering the hypothesis of different types of neglect following right and left brain lesion, it may not be surprising to discover that most of the patients showing ipsilesional neglect suffered from left or bilateral brain damage. This fact is in line with the hypothesis that when the brain lesion encompasses the dominant hemisphere, the resulting neglect syndrome may not present the strong "contralesional aspect" typical of neglect syndrome after unilateral right hemisphere lesions and, in turn, that damage to either hemisphere may lead to qualitatively different forms of neglect due to an impairment at different stages of a similar cognitive process.

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