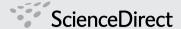
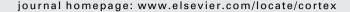


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Special issue: Research report

Representational neglect in "invisible" drawing from memory

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ARTICLE INFO

Article history:
Received 14 June 2007
Reviewed 14 October 2007
Revised 2 January 2008
Accepted 11 March 2008
Published online 11 July 2008

Keywords: Spatial neglect Drawing Visual feedback

ABSTRACT

We describe the case of a patient with right hemisphere damage and left unilateral neglect. The patient was asked to draw from memory common objects, either with or without visual feedback. In the conditions without visual feedback the patient was either blindfolded or he made "invisible" drawings using a pen with the cap on, the drawings being recorded with carbon paper underneath.

Results showed more neglect without than with visual feedback, contrary to previously published cases. This patient's pattern of performance may result from the contribution of a deficit of spatial working memory. Alternatively or in addition, the patient, who was undergoing cognitive rehabilitation for neglect, may have found easier to compensate for his neglect with visual feedback, which allowed him to visually explore the left part of his drawings.

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1. Introduction

Patients with unilateral spatial neglect fail to take notice of information coming from the side opposite to a brain lesion. The neglected stimuli can be physical (perceptual neglect), but also imagined (representational neglect), as when patients "forget" to describe from memory left-sided details of known places (Bisiach and Luzzatti, 1978). Many tasks are used to assess spatial neglect, such as cancellation, copying a figure, drawing objects from memory, or describing places from

memory. Each of them can reveal different aspects of neglect, but some tests appear to be less sensitive than others (Azouvi et al., 2002).

Constructional tests, like drawing, are often used to evaluate perceptual and representational abilities. Dissociations of performance on these tests have been described, and have brought about different interpretations. Several studies have explored the influence of visual feedback in drawing test and its relation with neglect. For example, Chokron et al. (2004) have studied the role of vision in spatial

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representation, using tasks of drawing from memory. Patients were requested to draw common objects from memory either with their eyes open or while blindfolded. The results showed that some of the patients showed less neglect without than with visual input, thus confirming previous similar findings (Anderson, 1993). Chokron et al. explained their results in terms of an attentional bias, consisting in a "magnetic" capture of attention by the right-sided visual details the patient had just drawn (see Gainotti et al., 1991), which was obviously absent when visual details were suppressed by blindfolding. A similar conclusion was drawn by Mark et al. (1988), who used variants of a cancellation task. Mark et al. had 10 patients with left neglect erase lines or draw over them by a pencil mark, and found less neglect in the 'erase' than in the 'draw' condition. Mark et al. concluded that right-sided lines attracted patients' attention when they were crossed by a pencil mark; rendering these lines invisible by erasing them obviously nullified this effect, thus decreasing neglect. However, findings apparently conflicting with this account were reported in another cancellation study (Wojciulik et al., 2004), where more items were cancelled using visible marks than using invisible marks (a pen with the cap on), perhaps because in the absence of visual markers patients failed to remember which locations they had already visited (see also Husain et al., 2001; Malhotra et al., 2005). If so, then some patients might show less neglect with than without visual feedback even when drawing from memory. Here we present the case of a patient who shows this pattern of performance.

2. Case report

AG is a 62-years old right-handed man with 10 years of schooling. He suffered an ischemic stroke 10 months before our observation. MRI showed hemorrhagic subcortical lesion involving the white matter of the right hemisphere, the lenticular nucleus, the thalamus and the internal capsule (Fig. 1). After the stroke, the patient had complete left hemiplegia and extinguished left-sided stimuli on both the visual and the somatosensory modalities. He also showed signs of severe left visuospatial neglect, for which cognitive rehabilitation was undertaken. At the time of our observation (March 2005), AG was undergoing cognitive rehabilitation since 5 months. The most recent neuropsychological assessment

(performed in January 2005, see Table 1) revealed signs of left neglect and constructional apraxia; there was also a marked impairment of working memory, as shown by the patient's performance in the digit span test and in the necessity of frequent repetitions by the examiner of the test instructions during the evaluation. Unfortunately, visuospatial working memory was not evaluated. Neglect signs were evaluated using the BEN (Azouvi et al., 2002). Results of the neglect battery are reported in Table 2. Fig. 2 displays AG's performance when copying the linear drawing of a landscape, which demonstrated scene-based left neglect.

3. Procedure

AG was requested to draw six items from memory with or without visual control. The items were a spider, a carafe, a butterfly, a pair of trousers, a sun and an umbrella. To decrease the difficulty of drawing without visual feedback and to eliminate only visual and not visuomotor feedback, we added a further condition, namely drawing with eyes open but using a pen with the cap on, so that the drawing was visible only via carbon paper. Thus, the task consisted of three conditions: (A) drawing with eyes open; (B) drawing with eyes open but using a pen with the cap on; (C) drawing while blindfolded. The stimuli were drawn one by one in all three conditions in the following procedure: the experimenter pronounced the name of the item and then the condition in which the patient had to draw; the order of stimuli presentation and conditions was randomised for a total of 18 items. Following the procedure used by Chokron et al. (2004), we asked five independent judges to decide whether the drawing was complete or not (complete was coded as +1, incomplete as 0), and whether it was symmetric or not (symmetric, 0; asymmetric with more details on right side, +1; asymmetric with more details on left side, -1).

4. Results

Table 3 reports the mean of the three evaluations of the five judges for each drawing in the three conditions. In the absence of visual feedback (whether using carbon paper or blindfolding) the number of left-sided omissions was systematically larger as compared to the condition with visual

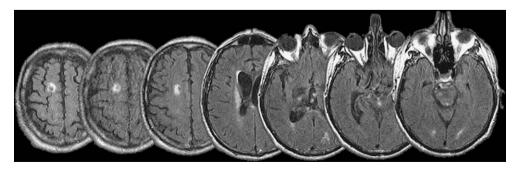


Fig. 1 – MRI showing a hemorrhagic subcortical lesion involving the white matter of the right hemisphere, the lenticular nucleus, the thalamus and the internal capsule.

Table 1 – Performance of AG on the general neuropsychological battery								
Test		Score						
WAIS-III	Picture completion Similarities/differences Block design Digit span	3 8 1 5						
Grober & Buschke	Immediate recall Total free recall Total free recall + cue Free differed recall Total differed recall Recognition Intrusions	14/16 6/48 28/48 3/16 10/16 4/16 22						
WCST		2 Criteria/3 18 Errors						
Stroop (45 sec version)	Words Colors Interference	20 sec; 1 error 24 sec 20 sec						
TMT	Part A Part B	780 sec Impossible						
Naming		63/80						
For test description see Lezak (1995).								

feedback. Visual feedback influenced the judgments of completeness (Friedman test, χ^2 corrected for ties = 11.47; d.f. 2; p=.0032), because drawings were judged as being more complete with than without visual feedback (Wilcoxon Signed Rank Test, free vision vs cap on, tied p-value = .026; free vision vs blindfolding, p=.027). A similar outcome was true for the judgments of symmetry (see Table 3 and Fig. 3). Analyses of the scores given by each of the five judges on the symmetry of each drawing showed that drawings made with visual feedback evoked more negative scores, indicating the presence of more details on the left side, than drawings made without visual feedback (spider, carafe and sun,

Table 2 – Performance of AG on the neglect battery								
Test	Score							
Bells test (max 15/15)	1/14							
Ogden figure copying ^a	0							
Clock drawing ^b	1							
Line bisection (% rightward deviation)	19.5							
Overlapping figures (max 10/10) ^c	3/8							
Line cancellation (max 30/30) ^d	27/30							
Letter cancellation (max 30/30) ^d	2/29							

Left/right correct responses are reported for the overlapping figures and the cancellation tests.

- a A 5-level scale is used, ranging from 0 (no omission) to 4 (omission of the left tree and of at least the left part of another item). AG made no omission on this task.
- b The scoring is: 0: normal performance; 1: omission or rightward displacement of a part of the five left sided hours; 2: omission or rightward displacement of all left sided hours. AG marked the hours from 12 to 6 in the appropriate positions, exclusively on the right half of the clock face.
- c $\,$ Number of items identified on the left/right half of the sheet.
- d Number of items cancelled on the left/right half of the sheet.



Fig. 2 - AG's performance when copying a linear drawing.

Friedman tests, all χ^2 corrected for ties > 6.69; d.f. 2; ps < .02). The umbrella and the butterfly were not recognizable in the blindfold condition, but the umbrella was more symmetrical when drawn with cap on than in free vision (Wilcoxon Signed Rank Test, tied p-value = .034) and there was a tendency in the same sense for the butterfly (Wilcoxon Signed Rank Test, tied p-value = .08). The trousers were not recognizable in the conditions without visual feedback; as a consequence, no statistical analysis was possible for this item. We note, however, that even figures judged as not recognisable (as the umbrella drawn while blindfolded, condition C in Fig. 3) demonstrated a rightward drawing bias.

5. Discussion

When drawing common objects from memory with or without visual feedback, patient AG demonstrated less neglect in the visual feedback condition. This contrasts with the performance of the patients reported by Chokron et al. (2004), who showed the opposite pattern of results, namely, more neglect with than without visual feedback. A straightforward possibility to explain this discrepancy is that these patients had different deficits, with preponderance of right attentional capture for the Chokron et al. patients and of a left representational impairment for the present patient. In this sense, these patterns of performance might reflect a double dissociation, suggesting an impairment of independent systems. Since, however, the dissociation is "weak"

Table 3 – Means of the judgements of completeness and symmetry given by five independent judges on the patient's drawings

	Con	Completeness			Symmetry		
	Α	В	С	Α	В	С	
Spider	0.8	0.6	0.6	-1	+0.8	+1	
Carafe	1	0.8	0.2	+1	+0.2	-0.4	
Butterfly	1	0	0	+0.4	+1	nr	
Trousers	0.6	0	0	+0.4	nr	nr	
Sun	1	0	0	-0.2	+1	+1	
Umbrella	0.6	0	0	-0.8	+1	nr	
Average	0.83	0.23	0.13	-0.03	0.80	0.53	

A= drawing with eyes open; B= drawing with eyes open but using a pen with the cap on; C= drawing while blindfolded.

Completeness: 1 = complete; 0 = incomplete.

Symmetry: 0 = symmetrical; +1 = asymmetrical with right side > left side; -1 = left side > right side; nr = not recognizable.

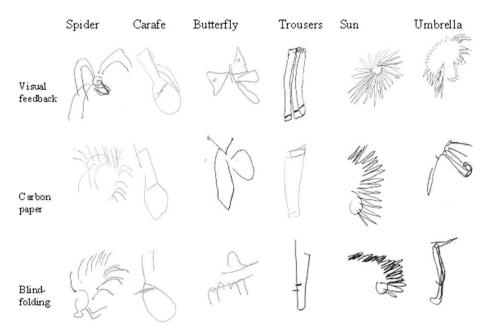


Fig. 3 - AG's performance when drawing from memory with and without visual feedback.

(i.e., the patient was impaired in both conditions; see Vallar, 2000) the impairment should involve more than one factor, e.g., a supramodal system and a more proprioceptive/imagery-based specific component. A possible alternative interpretation would be that vision provided additional support to performance. This interpretation based on a "double code", however, seems inconsistent with the evidence for a double dissociation in exploratory tasks (Cubelli et al., 1991; Vallar et al., 1991), and by the comparison between the pattern of the present patient and of the patients reported by Chokron et al. (2004).

On the other hand, an account exclusively based on a representational impairment in AG leaves unexplained the *decrease* of neglect with visual feedback in this patient. A lateralized impairment of a mental representation of space (see Bisiach and Luzzatti, 1978) should influence drawing performance independently of the presence or absence of visual feedback.

A possibility to explain the decrease of neglect with visual feedback in patient AG is to invoke the additional contribution to performance of a deficit of spatial working memory. As mentioned in Section 1, Wojciulik et al. (2004) hypothesized such a deficit to account for the performance of a sample of neglect patients on a modified cancellation test. Similar to the present procedure, patients marked each target either using a normal pen, or a pen with the cap on, so that the markings resulted invisible. Patients cancelled more items with visible than with invisible marks. Thus, visual feedback improved patients' performance, and the authors concluded that failure to cancel the left items on the contralateral side in the condition employing invisible marks was due to a deficit of spatial working memory, required to keep track of previously found items only when marked invisibly (see also Husain et al., 2001). When present, such deficits can exacerbate left neglect on visual search tasks (Malhotra et al., 2005). According to this hypothesis, in the absence of visual feedback AG was more likely to forget what he had already

drawn, and to perseverate in making (invisible) pen strokes on the right, ipsilesional side. Unfortunately, spatial working memory was not formally assessed in this patient, thus we can only speculate that the perseverations on the right side (e.g., spider, sun) were more frequent in the absence of visual feedback because AG could not keep track of the pen strokes he had just made when he could not see them (see Wojciulik et al., 2004; note, however, that Ronchi et al., 2009, this issue, found no evidence of an association between impairments of spatial working memory and perseveration in drawing and cancellation).

Alternatively or in addition, one might surmise that AG, who was undergoing cognitive rehabilitation for neglect, tried to compensate for his neglect in the perceptual domain. Neglect rehabilitation may have enhanced leftward voluntary orienting of visual attention, thus reducing the perceptual but not the representational aspects of neglect (see Bartolomeo et al., 1994; Bartolomeo and Chokron, 2001). That is, patients may learn with time (and possibly the help of people around them) to compensate for their neglect in the visuospatial domain, but not in the more abstract imaginal domain, which is not the object of rehabilitation or of more informal reminders to "look at your left". Follow-up studies of patients with an initial association of perceptual and imaginal neglect demonstrated results consistent with this hypothesis. Eight months after the first testing, a patient with initially severe neglect in the two domains had recovered from perceptual neglect, but still showed representational neglect (Bartolomeo et al., 1994). Another patient (D'erme et al., 1994) did not show clinical signs of neglect 8 days after the stroke; he had, however, mild but definite left neglect signs on visuospatial testing and on imaginal tasks. Two weeks after the stroke, perceptual neglect had resolved, leaving an isolated representational neglect, which disappeared in turn 22 days after onset (see Fig. 5 in Bartolomeo and Chokron, 2001). Patient MN, described by Coslett (1997) and Coslett and Saffran (1989)

also showed a similar pattern of selective recovery from perceptual, but not from representational, neglect. This account applies, of course, only to patients who present with an association of neglect in the two domains. This may not be the more common occurrence, because only about a third of patients with perceptual neglect also show signs of representational neglect (Bartolomeo et al., 1994; Bartolomeo et al., 2005). Further evidence consistent with the role of vision in neglect compensation comes from a study investigating vibrotactile reaction times (Pierson-Savage et al., 1988). In this study, patients with left perceptual neglect performed a reaction time task with the stimulated and responding (right) limb placed either ipsilaterally in right hemispace, or across the midline in contralateral (left) hemispace. Neglect patients who had had little or no rehabilitation made slower responses on the left than on the right, but most rehabilitated patients showed the opposite tendency. When, however, the same rehabilitated patients were tested with the eyes closed, the asymmetry of performance reverted to that shown before rehabilitation. Also in this case was neglect compensation only evident with visual feedback, when visual exploratory scanning could be used.

If we ever needed a further source of complication in the difficult enterprise of dissecting the mutually interacting component deficits of neglect, then the possibility that the (often neglected) influence of compensatory strategies may be as domain-selective as the deficits themselves stands there for our consideration.

Acknowledgments

Supported by grants from Assistance Publique – Hôpitaux de Paris (Interface Program) and Université Pierre et Marie Curie – Paris6 (Bonus Qualité Recherche) to P.B. C.C. is now at Laboratory for Behavioral Neurology and Imaging of Cognition, Department of Neurology, University Hospital of Geneva, Geneva, Switzerland & Swiss Center for Affective Sciences CISA – University of Geneva, Geneva, Switzerland.

REFERENCES

- Anderson B. Spared awareness for the left side of internal visual images in patients with left-sided extrapersonal neglect. Neurology, 43: 213–216, 1993.
- Azouvi P, Samuel C, Louis-Dreyfus A, Bernati T, Bartolomeo P, Beis J-M, et al. Sensitivity of clinical and behavioural tests of spatial neglect after right hemisphere stroke. *Journal of Neurology, Neurosurgery and Psychiatry*, 73: 160–166, 2002.
- Bartolomeo P, Bachoud-Levi A-C, Azouvi P, and Chokron S. Time to imagine space: a chronometric exploration of

- representational neglect. Neuropsychologia, 43: 1249–1257, 2005.
- Bartolomeo P and Chokron S. Levels of impairment in unilateral neglect. In Boller F, and Grafman J (Eds), Handbook of Neuropsychology. Amsterdam: Elsevier Science Publishers, 2001: 67–98
- Bartolomeo P, D'erme P, and Gainotti G. The relationship between visuospatial and representational neglect. *Neurology*, 44: 1710–1714, 1994.
- Bisiach E and Luzzatti C. Unilateral neglect of representational space. Cortex, 14: 129–133, 1978.
- Chokron S, Colliot P, and Bartolomeo P. The role of vision on spatial representations. Cortex, 40: 281–290, 2004.
- Coslett HB. Neglect in vision and visual imagery: a double dissociation. *Brain*, 120: 1163–1171, 1997.
- Coslett HB and Saffran EM. Evidence for preserved reading in 'pure alexia'. Brain, 89: 327–359, 1989.
- Cubelli R, Nichelli P, Bonito V, De Tanti A, and Inzaghi MG.
 Different patterns of dissociation in unilateral spatial neglect.
 Brain and Cognition, 15: 139–159, 1991.
- D'Erme P, Bartolomeo P, Gainotti G. Difference in recovering rate between visuospatial and representational neglect. In: Program and Abstracts, International Neuropsychological Society, 17th Annual European Conference; 1994. p. 49.
- Gainotti G, D'erme P, and Bartolomeo P. Early orientation of attention toward the half space ipsilateral to the lesion in patients with unilateral brain damage. Journal of Neurology, Neurosurgery and Psychiatry, 54: 1082–1089, 1991.
- Husain M, Mannan S, Hodgson T, Wojciulik E, Driver J, and Kennard C. Impaired spatial working memory across saccades contributes to abnormal search in parietal neglect. *Brain*, 124: 941–952, 2001.
- Lezak M. Neuropsychological Assessment. 3rd ed. New York: Oxford University Press, 1995.
- Malhotra P, Jager HR, Parton A, Greenwood R, Playford ED, Brown MM, et al. Spatial working memory capacity in unilateral neglect. *Brain*, 128: 424–435, 2005.
- Mark VW, Kooistra CA, and Heilman KM. Hemispatial neglect affected by non-neglected stimuli. Neurology, 38: 640–643, 1988
- Pierson-Savage JM, Bradshaw JL, Bradshaw JA, and Nettleton NC. Vibrotactile reaction times in unilateral neglect. The effects of hand location, rehabilitation and eyes open/closed. *Brain*, 111: 1531–1545, 1988.
- Ronchi R, Posteraro L, Fortis P, Bricolo E, and Vallar G. Perseveration in left spatial neglect: drawing and cancellation tasks. *Cortex*, 45: 300–312, 2009.
- Vallar G. The methodological foundations of human neuropsychology: Studies in brain-damaged patients. In Boller F, Grafman J, and Rizzolatti G (Eds), Handbook of Neuropsychology. 2nd ed. Amsterdam: Elsevier, 2000: 305–344.
- Vallar G, Rusconi ML, Geminiani G, Berti A, and Cappa SF. Visual and nonvisual neglect after unilateral brain lesions: modulation by visual input. *International Journal of Neuroscience*, 61: 229–239, 1991.
- Wojciulik E, Rorden C, Clarke K, Husain M, and Driver J. Group study of an "undercover" test for visuospatial neglect: invisible cancellation can reveal more neglect than standard cancellation. Journal of Neurology, Neurosurgery and Psychiatry, 75: 1356–1358, 2004.