# VISUAL PERCEPTION AND VERBAL DESCRIPTIONS AS SOURCES FOR GENERATING MENTAL REPRESENTATIONS: EVIDENCE FROM REPRESENTATIONAL NEGLECT

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In the majority of investigations of representational neglect, patients are asked to report information derived from long-term visual knowledge. In contrast, studies of perceptual neglect involve reporting the contents of relatively novel scenes in the immediate environment. The present study aimed to establish how representational neglect might affect (a) immediate recall of recently perceived, novel visual layouts, and (b) immediate recall of novel layouts presented only as auditory verbal descriptions. These conditions were contrasted with reports from visual perception and a test of immediate recall of verbal material. Data were obtained from 11 neglect patients (9 with representational neglect), 6 right-hemisphere lesion control patients with no evidence of neglect, and 15 healthy controls. In the perception, memory following perception, and memory following layout description conditions, the neglect patients showed poorer report of items depicted or described on the left than on the right of each layout. The lateralised error pattern was not evident in the non-neglect patients or healthy controls, and there was no difference among the three groups on immediate verbal memory. One patient showed pure representational neglect, with ceiling performance in the perception condition, but with lateralised errors for memory following perception or following verbal description. Overall, the results indicate that representational neglect does not depend on the presence of perceptual neglect, that visual perception and visual mental representations are less closely linked than has been thought hitherto, and that visuospatial mental representations have similar functional characteristics whether they are derived from visual perception or from auditory linguistic descriptive inputs.

Unilateral spatial neglect is characterised by an inability to report details from one hemispace of the immediate environment and/or from mental reconstructions of familiar scenes. The former is referred to as "perceptual neglect" (cf. Albert, 1973; Poppelreuter, 1991) and the latter as "representa-

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tional neglect" (cf. Bisiach & Luzzatti, 1978; Zingerle, 1913). These cognitive impairments are generally associated with damage to the brain hemisphere contralateral to the impaired hemifield. Several patients have been reported with both forms (cf. Bartolomeo, D'Erme, & Gainotti, 1994; Grossi, Modafferi, Pelosi, & Trojano, 1989), a finding suggesting close links between perception and mental representations. However, a few patients have been reported with pure perceptual neglect (Bartolomeo et al., 1994; Cantagallo & Della Sala, 1998; Coslett, 1997), and there are several reports of patients with pure representational neglect in the absence of any perceptual neglect (Beschin, Cocchini, Della Sala, & Logie, 1997; Coslett, 1997; Guariglia, Padovani, Pantano, & Pizzamiglio, 1993). This neuropsychological double dissociation suggests that links between perception and representation are less direct than has been suggested hitherto (cf. Farah, 1989; Finke, 1989; Kosslyn, 1994).

The phenomenon of pure representational neglect offers an opportunity to study the nature of mental representations and how they are generated. It also has implications for theories of cognition in the healthy brain; for example, one traditional view is that perceptual input is transferred to, and held in, a short-term working memory prior to its transfer to long-term memory. This assumption was explicit in the early models of short-term memory (e.g., Atkinson & Shiffrin, 1968), and is maintained in many contemporary introductory textbooks on memory. It is also present in Kosslyn's current model of visual imagery (cf. Kosslyn & Thompson, 2000).

One possible account for representational neglect is that it reflects an impairment of visuospatial working memory (Baddeley & Lieberman, 1980; Beschin et al., 1997; Bisiach, 1993). If working memory acts as a gateway between perception and long-term memory, then an impairment of working memory should also impair processing of perceptual input. The fact that patients are observed with representational neglect in the absence of perceptual neglect suggests that perceptual input does not rely on working memory to access long-term memory. Moreover, evidence that perceptual neglect patients can demonstrate implicit processing of perceptual input (e.g., Marshall & Halligan, 1988) again suggests that perceptual input directly activates long-term stored knowledge independently of the working memory system.

An alternative view of on-line information processing is to suggest that working memory comprises the currently activated portion of long-term memory (e.g., Hasher & Zacks, 1979; Stoltzfus, Hasher, & Zacks, 1996). Such a view has difficulty with evidence from numerous patients who show deficits of working memory (including representational neglect) in the absence of any impairments of long-term memory. So, for example, representational neglect patients may fail to retrieve items on the neglected side of an imagined familiar town square or room, but they can readily retrieve the missing information when asked to imagine the scene from the opposite perspective (e.g., Bisiach & Luzzatti, 1978). This again points to a difficulty in working memory that is quite distinct from long-term storage (Ellis, Della Sala, & Logie, 1996).

The dissociation between perceptual neglect and representational neglect is more readily explained by assuming that perception directly activates the contents of long-term memory, and the product of these activations is then held and manipulated in working memory (e.g., Baddeley & Logie, 1999; Beschin et al., 1997; Logie, 1995, 1996). Such a model would allow for impairments with perceptual input that do not impinge on the representational system in working memory. Conversely, impairments of the visuospatial representational system should not necessarily lead to deficits in the processing of perceptual input. Specifically, the perceptual processes seem to be intact in pure representational neglect patients, as does the ability to access the stored knowledge required for object recognition. It appears that the links between perception and long-term memory are functioning normally, but that the system for temporary representation and manipulation of visuospatial information is impaired.

The dissociations between perception and mental representation found in neglect contrast with the numerous studies of mental imagery in healthy adults that indicate some degree of functional similarity between the processing of percepts and of images. For example, visual recognition is primed by mental representations of corresponding objects (e.g., Ishai & Sagi, 1997). Studies of mental scanning have provided evidence that the chronometric patterns of mental exploration of visual images are similar to those of visual scanning across perceived objects. This is generally taken as evidence for the functional similarities of imagery to visual perception, as well as the structural isomorphism between imaginal representations and visual percepts (e.g., Denis & Kosslyn, 1999; Kosslyn, Ball, & Reiser, 1978). Moreover, studies using neuroimaging techniques (ERP, fMRI, and PET) have shown that some of the brain areas activated during visual perception tasks are also activated during imagery tasks (e.g., Farah, Weisberg, Monheit, & Péronnet, 1989; Kosslyn, Thompson, Kim, & Alpert, 1995). However, other neuroimaging studies have demonstrated that although there may be an overlap, nevertheless important areas of cortex are activated during imagery tasks, but are not activated in perception, and vice versa (e.g., Mellet et al., 2000; Mellet, Tzourio, Denis, & Mazoyer, 1995). In this context of conflicting evidence, a more detailed study of the phenomenon of neglect might lead to additional insight.

The debate as to whether mental images function as isomorphs of visual perception has been revisited following more recent evidence that the structural properties of images are not uniquely determined by their visual origin. Whereas the early arguments for the similarities of perceptual and imaginal representations have been based on situations in which representations have been derived from previous visual perceptual experience, there is much to gain from investigating the properties of images constructed in the absence of recent or more remote visual experience. When people are presented with verbal descriptions of spatial configurations and invited to generate and extract information from visual images depicting these configurations, their performance patterns are similar to those typical of tasks involving mental imagery derived from visual perception. This is true in particular for mental scanning and the mental comparison of distances in images generated from auditory verbal descriptions (cf. Bricogne et al., 1999; Denis, 1996; Denis & Cocude, 1992; Denis, Gonçalves, & Memmi, 1995). Such findings are thought to reflect the analogue nature of mental images, whether their origin is visual perceptual or auditory verbal.

Although performance patterns from tasks involving memory following visual perception and memory following verbal descriptions have offered significant insight for the functioning of the healthy brain, there have been very few attempts to use such procedures with patients suffering from representational neglect (but see Bisiach, Capitani, Luzzatti, & Perani, 1981). The study of memory following perception is clearly only useful in cases of pure representational neglect; otherwise, lateralised performance impairments in recall could be attributed to the presence of the perceptual neglect. The resulting impoverished perceptual input would then lead to an impoverished representation even if the representational system itself was unimpaired. Beschin, Basso, and Della Sala (2000) reported one of the few patients in whom such a procedure was explored. Their patient had the very rare combination of a right hemifield perceptual neglect and a left hemifield representational neglect following bilateral lesions. The patient was presented with pictures of objects to be reproduced from memory after each picture had been withdrawn. Under these circumstances, the patient reproduced only the right half of the object. The patient succeeded in reproducing the left side of the picture while it was in view. However, under this perceptual condition, the right half of the object was missing. This pattern clearly demonstrated that representational problems did not arise from a failure of perception. Clearly, there is a need for detailed exploration of memory based on recent visual experience in pure representational neglect. Moreover, there are no studies of which we are aware in which representational neglect patients have been asked to generate and report on mental representations based on auditory verbal descriptions. This paper explores the above paradigms in a series of right-hemisphere-damaged patients and healthy controls.

In this study, we collected verbal reports of scenes by neglect patients. A perceptual condition was contrasted with two conditions where the reports were based on mental representations. In one case, the representations were constructed from visually perceived information, whereas in the other case, the representations were constructed from auditory verbal descriptions. Thus, both conditions involved retrieving information from memory, while the representations derived from different input modalities. Our aim was two-fold. First, if we obtained evidence for representational neglect for scenes recently viewed, it would demonstrate that representational neglect is not limited to impairments in access to long-term memory. Second, if representational neglect was found for mental representations of scenes that have not been derived from visual perceptual input, this would indicate that neglect extends from visual perception to the processing of purely mental constructs referring to visual space. Moreover, such an outcome would lend support to the suggestion that mental representation has considerable autonomy from perception.

## METHOD

### Participants

Seventeen right-handed patients (13 males, 4 females) with a right-hemisphere lesion resulting from cerebrovascular accident were included in the study. They were recruited from the Rehabilitation Department of Somma Lombardo, Gallarate, Italy. None of them suffered from brain tumour or head injury. Their average age was 60.8 years (*SD* = 12.5). Mean educational level was 7.5 years (*SD* = 3.3). Table 1 shows their demographic and clinical characteristics. A further 15 participants (6 males, 9 females) were selected as controls matched for age

**Table 1.** *Demographical and clinical features of the patient participants*

| *Patients* | *Age* | *Sex* | *Education (years)* | *Lesion Type* | *Lesion Site* | *Interval from onset (days)* | *Left Paresis* | *Verbal judgement score* |
|---|---|---|---|---|---|---|---|---|
| *Without neglect* | | | | | | | | |
| 1 | 75 | F | 6 | I | Fr-P | 60 | + | 48 |
| 2 | 74 | M | 8 | I | Fr-P | 200 | + | 38 |
| 3 | 61 | M | 13 | I | P,ic | 210 | + | 40 |
| 4 | 44 | M | 5 | I | P-O | 60 | + | 48 |
| 5 | 65 | M | 8 | I | T,bg | 150 | + | 50 |
| 6 | 71 | F | 5 | I | P | 200 | + | 40 |
| *With representational neglect* | | | | | | | | |
| 7 | 56 | F | 5 | I | Fr-P | 90 | + | 52 |
| 8 | 61 | M | 5 | I | P-T | 100 | + | 42 |
| 9 | 56 | M | 12 | I | Fr-P-T | 180 | + | 54 |
| 10 | 44 | M | 15 | I | P-T,bg,ic | 210 | + | 44 |
| 11 | 79 | M | 6 | I | Fr-P-T | 60 | + | 48 |
| 12 | 34 | M | 11 | H | bg | 50 | + | 56 |
| 13 | 78 | F | 5 | H | P-O | 40 | + | 38 |
| 14 | 55 | M | 5 | I | Fr-P-T,bg | 50 | + | 38 |
| 15 | 61 | M | 5 | H | P-T | 180 | + | 50 |
| *With perceptual neglect only* | | | | | | | | |
| 16 | 57 | M | 8 | I | F-P-O | 30 | + | 56 |
| 17 | 62 | M | 5 | I | P-O | 30 | + | 54 |

I = ischaemic stroke; H = haemorrhagic stroke; Fr = frontal; P = parietal; O = occipital; T = temporal; bg = basal ganglia; ic = internal capsula.

(mean = 61.7, *SD* = 7.1) and educational level (mean =6.3, *SD* =2.4) with the patients. They were recruited from visitors to the hospital and friends and relatives of the patients.

All patients were tested for verbal intelligence using the Verbal Judgement Test (range = 0–60, cutoff score =32; cf. Spinnler & Tognoni, 1987; see Table 1). None of the patients included in the study showed any signs of global deterioration. All patients underwent a standard neurological examination that encompassed the detection of paresis, visual field defects, and extinction (Bisiach, Cappa, & Vallar, 1983). Extinction was tested in all modalities whenever possible. The procedure, scoring and cutoff reported by Cocchini, Cubelli, Della Sala, and Beschin (1999) were followed. Scores for condition (including each visual quadrant) ranged from 0 to 10. To avoid confusion between visual field defect and extinction, both stimuli were presented simultaneously in the spared quadrants of the visual field (i.e., in the case of a left lower—inferior—quadrantanopia, stimuli in the visual extinction test were presented simultaneously in the right and left upper—superior—quadrants, which were spared). The data for patients are shown in Table 2.

## Tests for neglect

The patients were tested with a battery of neuropsychological tests drawn from previous literature and designed to detect the presence of perceptual and/or representational neglect. In all cases, the diagnosis of neglect was based on the difference in performance between the left and the right hemispace.

### *Perceptual tests requiring motor response*

*Line cancellation (Albert, 1973).* This test requires the participants to cross out short lines arranged randomly on a sheet. There are no distractors. The test shows neglect when participants omit at least one stimulus on the left, but none on the right (Albert, 1973). If omissions are present on the right as well, then neglect would be diagnosed if omissions on the left are at least three times those on the

**Table 2.** *Presence or absence of left visual field defects and left extinction in patient participants*

| Patients | Left visual field defects | Left extinction: Visual | Left extinction: Auditory | Left extinction: Tactile |
|---|---|---|---|---|
| *Without neglect* | | | | |
| 1 | No | No | No | No |
| 2 | No | No | Sensory deficits | Yes |
| 3 | No | No | No | No |
| 4 | Superior quadrant | Yes | No | No |
| 5 | Superior quadrant | Yes | Not assessed | No |
| 6 | No | No | No | No |
| *With representational neglect* | | | | |
| 7 | No | Yes | Yes | No |
| 8 | Inferior quadrant | Yes | Yes | Sensory deficits |
| 9 | Non testable | Non testable | Not assessed | Sensory deficits |
| 10 | No | Yes | Yes | Sensory deficits |
| 11 | Superior quadrant | Yes | Yes | Yes |
| 12 | No | Yes | No | Sensory deficits |
| 13 | Inferior quadrant | Yes | No | Yes |
| 14 | Inferior quadrant | Yes | Sensory deficits | Sensory deficits |
| 15 | No | No | No | No |
| *With perceptual neglect only* | | | | |
| 16 | Superior quadrant | Yes | Sensory deficits | Sensory deficits |
| 17 | Inferior quadrant | Yes | Yes | No |

right (Beschin et al., 1997; Nichelli, Rinaldi, & Cubelli, 1989).

*Star cancellation (Wilson, Cockburn, & Halligan, 1987).* This test requires the participants to cross out small stars among distractors. It shows neglect when participants omit at least one stimulus on the left, but none on the right (Wilson et al., 1987). If omissions are present on the right side as well, neglect is diagnosed if omissions on the left are at least three times those on the right (Beschin et al., 1997).

***Perceptual tests not requiring motor response***

*Reading of single words.* This test consists of reading 48 single words, short (4 letters) and long (up to 12 letters). Neglect is diagnosed if leftward errors (omissions or substitutions) are more than three times as frequent as the rightward errors (Beschin et al., 2000).

*Description of a scene.* The patients were asked to remember objects and characters shown in a complex picture. The score ranges were 0–22 and 0–18 for the left and right side, respectively. Neglect was diagnosed if participants scored 2 *SD*s deviations below the mean of controls (left, mean = 9.4, *SD* = 2.42; right, mean = 12.4, *SD* = 1.85; Beschin et al., 1997; Cocchini et al., 1999). There were no time limits in this test.

***Representational tests requiring motor response***

*Drawing from memory.* The patients were asked to draw a daisy based on their long-term stored knowledge. Neglect was considered present when omissions on the left were clearly observed (Robertson & Halligan, 1999).

*Drawing a clock from memory.* The patients were provided with the outline of a clockface and were asked to insert the numbers for the hours. Neglect was considered present when left-side numbers were omitted or drawn on the right (Anderson, 1993).

***Representational tests not requiring motor response***

*Description of a square from memory.* The patients were asked to describe a familiar city square first from a given perspective, and then, 1 week later, from the opposite perspective. Absolute scores were different because participants were assessed with different town squares (the central square of their home town). Neglect was diagnosed when the overall number of elements (sum of both viewpoints) reported on the left were half (or less) those reported on the right (Beschin et al., 1997; Bisiach & Luzzatti, 1978).

*Description of a novel scene from memory.* The patients inspected a picture (with 22 items on the left and 18 on the right) silently for 2 min, after which the picture was removed and they were asked to recall the items in the picture verbally. Neglect was diagnosed if participants scored below the cutoff based on the performance of a control group (Beschin et al., 1997). Cutoff scores were 5.0 for the left side and 3.2 for the right side.

Patients were diagnosed as being affected by perceptual neglect if they performed poorly on at least two of the four perceptual tests, and diagnosed as showing representational neglect if they performed poorly on at least two of the four representational tests.

On the basis of this initial screening, six patients showed no evidence of perceptual or representational neglect, and nine patients showed clear evidence for the presence of representational neglect. Of these latter patients, eight also showed signs of perceptual neglect. The ninth patient of this group (Case No. 15 in the tables) was a case of pure representational neglect. Below, we will refer to this group of nine patients as "patients with representational neglect." The final two patients showed only mild perceptual neglect. Results for the 11 patients showing neglect (Case Nos. 7 to 17) are shown in Table 3.

## Experimental materials

Ten groups of four objects were selected, and all the objects within any one group were drawn from the

**Table 3.** *Performance on tests assessing perceptual and representational neglect in patient participants*

| | *Perceptual tests* | | | | *Representational tests* | | | |
|---|---|---|---|---|---|---|---|---|
| | *With motor response* | | *Without motor response* | | *With motor response* | | *Without motor response* | |
| *Patients* | *A* | *B* | *C* | *D* | *E* | *F* | *G* | *H* |
| *With representational neglect* | | | | | | | | |
| 7 | — | — | + | + | + | + | + | + |
| 8 | + | + | + | + | + | + | + | + |
| 9 | + | + | — | + | — | — | + | + |
| 10 | + | + | + | — | + | — | + | — |
| 11 | + | + | + | — | + | + | + | + |
| 12 | + | + | + | — | + | — | + | — |
| 13 | + | + | + | + | + | + | + | + |
| 14 | + | + | + | + | + | + | — | + |
| 15 | — | — | — | — | — | + | + | + |
| *With perceptual neglect only* | | | | | | | | |
| 16 | + | + | + | + | — | — | — | — |
| 17 | + | + | + | + | — | — | — | — |

+ = presence of neglect; — = absence of neglect; A = line cancellation; B = star cancellation; C = reading of single words; D = description of a scene; E = drawing from memory; F = drawing a clock from memory; G = description of a square from memory; H = description of a novel scene from memory.

same category. For example, one group included four household objects (vase, coffee pot, ashtray, bottle), another one included four types of food (egg, cheese, pasta, salad), and so on. No object was repeated across groups. A 15 × 10 cm colour photograph of each object was prepared. A further nine groups of four object names were selected and arranged in short sentences (as described later).

## Procedure

The experimental procedure comprised four conditions. In the first condition (visual perception), each of five trials consisted of one group of four photographs of objects displayed at the extreme corners of two A3 sheets joined together to form a 58 x 41.5 cm area. The array was displayed on the table in front of the participants. The objects remained in view for 90 s, during which time the participants reported the name and location of the objects.

In the second condition (memory following visual perception), five trials, each involving four different objects, were presented visually following the same procedure as in the visual perception condition, except that the participants reported objects and locations from memory after the array was removed. The participants were invited to observe the objects for 90 s. They were told that they would be asked later to remember the objects and their positions. It was suggested to participants that they try to build a visual image of each scene. There were no time limits for the study phase. The objects were then withdrawn and the participants had to report the object names and their locations immediately from memory.

In the third condition (memory following description), there was no object array in view. Instead, on each of five trials, the experimenter spoke aloud the names of four objects and their locations. For example, "The cake is in front of the biscuit. The biscuit is on the left of the ice cream. The ice cream is behind the chocolate. The chocolate is on the right of the cake." It took about 90 s to read aloud the four sentences. The participants were instructed to build a visual image of the scene as it was being described. For each trial, the position of the first-named object was indicated by the experimenter on the table (e.g., to the right and closest to the participant). To control for possible recency effects in recall being confounded with object location, and to avoid the problem of "response bias" (Bisiach, Ricci, Lualdi, & Colombo, 1998), the position of the first-named object was counterbalanced across trials. Immediately after the final sentence of each description, the participant was asked to recall the objects and their locations.

In the fourth condition (verbal memory only), each of four trials consisted of a series of four sentences stating arbitrary nonspatial properties of objects. For example, "The pencil is expensive. The penknife is large. The scissors are long. The eraser is nice." Participants were to recall the objects and their properties. This condition served as an assessment of general verbal memory ability against which to assess any performance impairment in the memory following visual perception and the memory following description conditions[1].

Within each condition, the order of presentation of the groups of objects was fixed. Each participant was assigned to one of four different orders of presentation of the four conditions.

## Retest

In order to assess the reliability of our results, we retested a number of participants on the first three conditions (visual perception, memory after visual perception, memory after description) after periods ranging from 7 to 30 days. It was possible to retest four controls, three patients without neglect, five patients with representational neglect, and the two patients showing only perceptual neglect.

# RESULTS

In each condition, two scoring methods were employed. The more conservative method counted as an error both the omission of an object and recall of an object in an incorrect position (e.g., left–right transpositions). The more lax criterion counted only the number of omissions. In the results shown next, we will focus on the data from the three main groups: controls ($N = 15$), patients without neglect ($N = 6$), and patients with representational neglect ($N = 9$). Data from the two pure perceptual neglect patients will be reported in the text when relevant.

## Visual perception

Figure 1 shows the mean number of correct items reported by each group based on the conservative scoring method. From the figure, it is clear that the controls and patients without neglect performed at ceiling. The patients with representational neglect reported significantly fewer items from the left than from the right of the arrays, $t(8) = 3.36, p < .01$. The two mild pure perceptual neglect patients performed at ceiling. The data using the lax scoring criterion were identical to those using the conservative criterion for all groups.

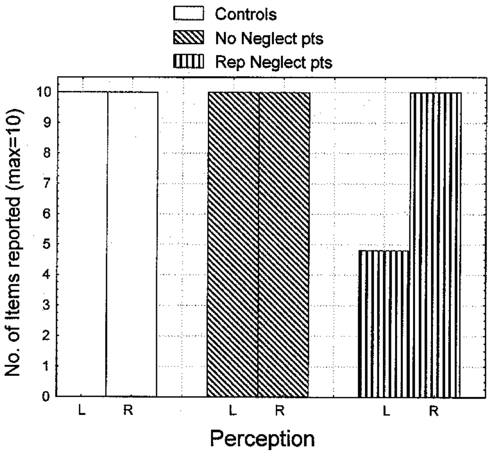


**Figure 1.** *Mean number of items reported in correct left or right positions by controls, patients without neglect, and patients with representational neglect (visual perception condition).*

[1] In a pilot study, in order to equate the procedure across conditions, we used five sets of four relational statements such as: "The pineapple is more yellow than the pear. The pear is less sweet than the orange, etc." However, this resulted in generating larger numbers of errors for the participants compared with the other three experimental conditions. Therefore, we adopted a slightly less demanding set of materials. The procedure we adopted resulted in broadly equivalent performance levels across conditions for the control participants.

## Memory following visual perception

Figure 2 shows the mean number of items correctly recalled in their correct positions. The data for the controls were included in a 2 x 2 repeated-measures analysis of variance (ANOVA) comparing visual perception with memory following visual perception as one factor and left versus right as the second factor. The analysis showed that memory performance was poorer than perceptual report, $F(1, 14) = 21.76$, MSE $= 0.99$, $p < .001$. There was no significant difference between left and right, and no interaction. An identical pattern was obtained when using the lax scoring method, with a highly significant effect of conditions, $F(1, 14) = 20.48$, $MSE = 0.16$, $p < .001$.

The data for the patients without neglect were analyzed in the same way. There was a marginal difference between visual perception and memory following visual perception, $F(1, 5) = 6.17$, $MSE = 9.24$, $p = .056$. There was no evidence for lateralisation and no interaction. The lax criterion showed a very similar pattern except that the effect of conditions was not significant.

The data for the patients with representational neglect showed significantly poorer performance in the memory following visual perception condition, $F(1, 8) = 5.92$, $MSE = 4.51$, $p < .05$, and significantly poorer report for items depicted on the left, $F(1, 8) = 19.52$, $MSE = 15.69$, $p < .005$. There was no significant interaction. The lax criterion showed no difference between the conditions, but performance was significantly poorer for items on the left, $F(1, 8) = 20.99$, $MSE = 15.44$, $p < .005$. There was no interaction. Within the memory following visual perception condition, the left/right difference was confirmed by significant $t$ values when using either the strict or the lax criterion, $t(8) = 5.57$, $p < .001$, and $t(8) = 4.35$, $p < .005$, respectively. With both scoring methods, all nine patients reported fewer items from the left than from the right.

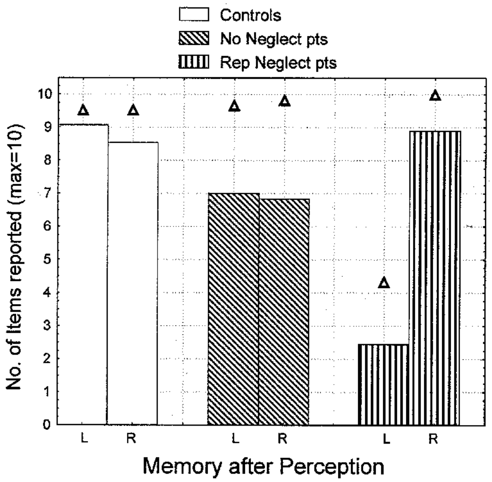


**Figure 2.** *Mean number of items reported in correct left or right positions by controls, patients without neglect, and patients with representational neglect (memory following visual perception condition). Triangles show the corresponding values for each column when the lax criterion is used.*

The two pure perceptual neglect patients showed poor performance in the memory following visual perception condition, and a modest tendency to recall fewer items on the left than on the right (mean = 6.5 and 8.0, respectively). This was confirmed when using the lax criterion, although overall scores were higher (mean = 8.5 and 10.0, respectively).

## Memory following description

Figure 3 shows the mean number of items recalled correctly in their correct positions. The data were included in an ANOVA that contrasted memory following visual perception with memory following description. The second factor was left versus right as before. The controls showed poorer performance in the memory following description condition, $F(1, 14) = 21.00$, $MSE = 1.61$, $p < .001$. There was no effect of lateralisation, and no interaction. For the more lax criterion, again the memory following description was poorer than memory following visual perception, $F(1, 14) = 14.91$, $MSE = 0.49$, $p < .005$. In addition, there was an overall tendency for fewer items to be recalled from the left, $F(1, 14) = 6.67$, $MSE = 0.30$, $p < .05$. There was no interaction.

The patients without neglect showed no difference between conditions, no effect of lateralisation, and no interaction. With the lax criterion, there was a marginal effect of conditions, $F(1, 5) = 6.36$, $MSE = 1.48$, $p = .053$. There was no effect of laterality and no interaction.

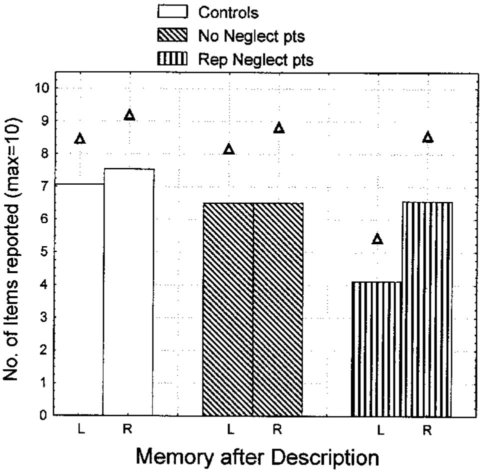


**Figure 3.** *Mean number of items reported in correct left or right positions by controls, patients without neglect, and patients with representational neglect (memory following description condition). Triangles show the corresponding values for each column when the lax criterion is used.*

The patients with representational neglect showed no difference between conditions, but showed a strong tendency for more errors on the left, $F(1, 8) = 32.16$, $MSE = 5.53$, $p < .001$, and a significant interaction, $F(1, 8) = 10.67$, $MSE = 3.38$, $p < .05$. The interaction indicates that the effect of neglect was stronger in memory following visual perception than in memory following description. As before, with the lax criterion, there was no difference between conditions, but performance was much poorer on the left, $F(1, 8) = 22.05$, $MSE = 7.86$, $p < .005$, and the interaction was marginal, $F(1, 8) = 4.79$, $MSE = 3.07$, $p = .06$. Within the memory following description condition, the left/right difference was confirmed by significant $t$ values whether the strict or the lax criterion was used, $t(8) = 3.05$, $p < .05$, and $t(8) = 3.63$, $p < .01$, respectively. With both scoring methods, eight out of the nine patients had more errors on the left than on the right. It is clear from Figures 2 and 3 that for the strict criterion, the patients with representational neglect showed poorer performance on the right in this condition when compared with memory following perception, although in both conditions there were more errors on the left. However, for items on the right, the lax criterion scores in Figure 3 are higher than the strict criterion scores and are very similar to those for the other two groups in this condition. This is not true for the errors on the left. Therefore, the overall pattern indicates that for the patients with representational neglect the errors on the right were mainly due to misremembering locations, whereas errors on the left were mainly omissions of items.

The two perceptual neglect patients showed poorer performance in the memory following description condition, but no effect of lateralisation (mean = 5.0 and 4.5, for left and right, respectively). The lax criterion resulted in much higher scores overall and a slight tendency for there to be more errors from the left (mean = 8.0 and 9.5, respectively). The data pattern was almost identical to that for the controls.

## Verbal memory only

Figure 4 shows the recall data in the verbal memory only condition. The recall rate was quite similar for the three groups of participants, as well as for the two pure perceptual neglect patients.

## Single case of pure representational neglect

One of the patients with representational neglect (Case No. 15) had no accompanying signs of perceptual neglect. Given the rarity of such patients, we examined this patient's data in more detail. The patient was male, 61 years old, right-handed, with 5 years of schooling. He had a haemorrhage in the

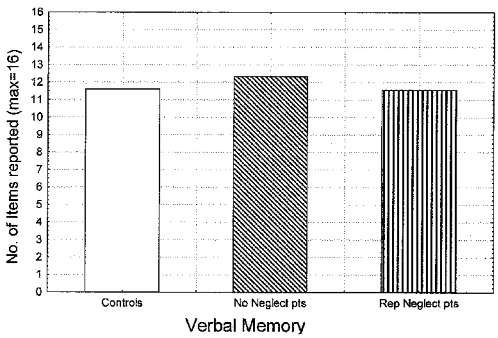


**Figure 4.** *Mean number of items reported by controls, patients without neglect, and patients with representational neglect (verbal memory only condition).*

territory supplied by the middle cerebral artery, and the CT scan showed a large lesion in the right temporal-parietal region.

Figure 5 shows his performance for the first three conditions when scores are based on the strict criterion. From the figure, it is clear that this patient showed ceiling performance on the visual perception condition, but he clearly tended to omit details on the left of the representation following visual perception and following description. His verbal memory score was 10, which was less than 1 *SD* from the mean score for the controls.

Figure 6 shows the data from Case No. 15 for the lax scoring method. It is immediately clear that his scores were much higher than those shown on Figure 5. There is still evidence for left-sided neglect on the two memory conditions. However, his performance pattern and scores are similar to those shown by the control participants on this lax scoring method. A comparison of Figures 5 and 6 suggests that this patient's errors arose largely from recalling items on the wrong side, that is, items on the left were reported as having appeared on the right. This observation reinforces the conclusion that his problems lay in his visuospatial representations, and did not result from a general impairment of memory or of perception. In the visual perceptual experimental condition and in the visual perceptual initial screening tests, the patient showed no tendency to use the word "right" any more than the word "left," indicating that the representational lateralisation errors were not the result of a general response bias. There is also an interesting contrast with the data of the two pure perceptual neglect patients (see earlier), from whom there was no evidence of lateralised errors in the memory following description condition.

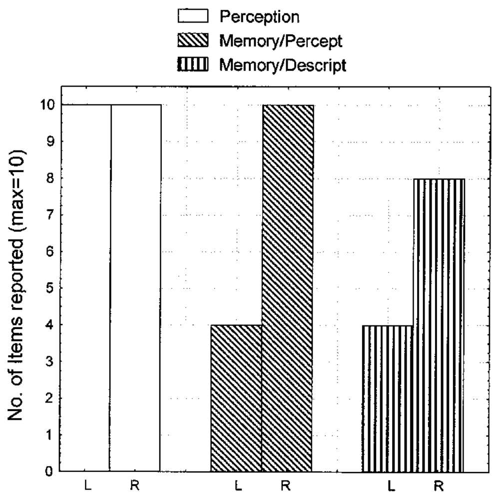


**Figure 5.** *Mean number of items reported in their correct left or right positions by one patient with representational neglect (case No. 15) in the visual perception, the memory following visual perception, and the memory following description conditions.*

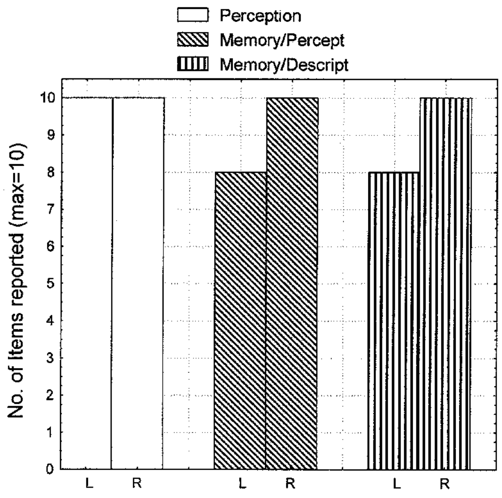


**Figure 6.** *Mean number of correct items reported irrespective of their positions by one patient with representational neglect (case No. 15) in the visual perception, the memory following visual perception, and the memory following description conditions.*

## Retest

Table 4 shows the mean number of items reported correctly in their correct positions for those participants tested on two occasions. Data from both testing sessions are shown. For control participants, the data patterns are virtually identical on both occasions for all three conditions. For the patients showing no neglect, a similar observation can be made. For the patients showing representational neglect, the pattern for the visual perception condition is similar on both occasions, whereas for memory following visual perception and memory following description, overall performance levels

**Table 4.** *Mean number of items reported in their correct left or right positions by participants tested on two occasions*

| | *Perception* | | *Memory following perception* | | *Memory following description* | |
|---|---|---|---|---|---|---|
| | *Left* | *Right* | *Left* | *Right* | *Left* | *Right* |
| *Controls (N = 4)* | | | | | | |
| First test | 10.0 | 10.0 | 9.0 | 8.0 | 7.0 | 7.3 |
| Second test | 10.0 | 10.0 | 9.3 | 9.0 | 7.5 | 7.8 |
| *Patients without neglect (N = 3)* | | | | | | |
| First test | 10.0 | 10.0 | 9.3 | 9.3 | 8.3 | 6.7 |
| Second test | 10.0 | 10.0 | 9.3 | 9.3 | 8.0 | 7.7 |
| *Patients with representational neglect (N = 5)* | | | | | | |
| First test | 4.8 | 10.0 | 2.4 | 8.4 | 4.6 | 5.8 |
| Second test | 5.0 | 10.0 | 4.0 | 9.2 | 6.2 | 7.6 |
| *Patients with perceptual neglect only (N = 2)* | | | | | | |
| First test | 10.0 | 10.0 | 6.5 | 8.0 | 5.0 | 4.5 |
| Second test | 10.0 | 10.0 | 9.0 | 8.0 | 8.5 | 8.5 |

are slightly higher on the second occasion, but the evidence for neglect remains. For the patients showing perceptual neglect only, there is no change in the pattern for the visual perception condition. Performance levels in the remaining two conditions appear to be higher on the second test, and the indication of mild representational neglect in memory following visual perception appears only on the first occasion.

## DISCUSSION

Our major aim was to explore further the nature of representational neglect and its possible dissociation from visual perception. In particular, most previous reports of representational neglect have focused on retrieval of familiar visuospatial information stored in long-term memory. Our results indicate that representational neglect also appears for visual information that has been perceived recently. The same results demonstrate that representational neglect is quite distinct and does not depend on the presence of perceptual neglect. Patients who show both forms nevertheless have impairments in their representations that could not have arisen from a perceptual problem.

Moreover, our results demonstrate that the representations of neglect patients can be impaired when built from auditory verbal descriptions, that is, without any recent or more remote inputs from visual perception. Patients with representational neglect do not appear to compensate for their deficit by using verbal codes, despite showing no verbal memory deficits. Therefore, the impact of neglect appears to be independent of the information source that is used to construct mental representations, whether the source involves visual perception or auditory verbal input. When coupled with the previous literature and our screening data on the patients, it is clear that representational neglect also does not arise from a loss of information from long-term memory.

The data from one of our patients add to the small number of cases of pure representational neglect that have been reported in the literature. Case No. 15 had no difficulty in describing objects coupled with no general memory impairment. His deficit was restricted to left omissions in retrieving from memory and reporting details from memory representations, as well as in drawing from memory. The visual or verbal source of these representations did not affect the nature or extent of his deficit. The comparison between our different scoring methods suggested that he had no difficulty in recalling the objects' identity, but that the majority of his lateralised errors arose from mistaken recall of locations. The same was true when comparing the strict and the lax criteria for all of the patients with representational neglect in the memory following description condition. This pattern is in contrast with the lack of evidence for lateralisation in the pure perceptual neglect patients in the same condition. The fact that errors made by the "pure" representational patient appeared mainly to be caused by mislocalised items in recall has interesting parallels with the phenomenon of allochiria, that is, a stimulus in a given position is referred to by the patient as being in the contralateral hemispace (cf. Bender & Nathanson, 1950; Beschin et al., 1997; Critchley, 1953; Meador, Allen, Adams, & Loring, 1991).

The results have implications that go beyond the understanding of representational neglect; they also provide insights into normal visuospatial cognition. As we argued in our introduction, there is now a body of evidence for the view that mental representation and perception are somewhat independent, and our data provide further support for this view, both from the double dissociations found among patients (representational neglect in the absence of perceptual neglect, and vice versa) and from the comparisons between our experimental conditions. With regard to the latter, we have shown that representational neglect can occur for material presented as auditory verbal descriptions, involving no visual perceptual input. This suggests that the damaged mental representational system that these patients use for constructing a representation from visual perception is most likely to be the same damaged representational system that they use to construct a representation from visual perceptual input. In other words, the mental representational system does not depend on visual perceptual input to form a representation from novel material, and this speaks to a dissociation between visual perception and mental representation.

On the basis of previous literature, including our own, we argued that visuospatial storage and processing in working memory might offer a candidate cognitive mechanism for constructing, hosting, maintaining, and supporting retrieval from a visuospatial mental representation. The argument from the data reported here and from our previous work, that the mental representation is independent of visual perception, also supports the idea that working memory is separate from visual perception. This contrasts with widely held assumptions that perceptual input "passes through" working memory on the way to long-term memory, and challenges the view that perception and mental representation are closely associated.

All of the patients reported here as having representational neglect appear to show impairments in a system that holds a temporary representation from a particular imagined viewpoint. The patients have no difficulty in identifying what the objects are, demonstrating that they have no difficulty in accessing knowledge about objects stored in long-term memory. This finding points to the idea that the contents of working memory are interpreted rather than being raw sensory images. In other words, perception feeds directly into long-term memory (not via working memory), and the contents of a separate working memory are derived from information that is activated from the store of knowledge in long-term memory (for detailed discussions, see Baddeley & Logie, 1999; Logie, 1995; Logie, Engelkamp, Dehn, & Rudkin, 2001).

A further implication pertains to the role of language as a medium for the construction of nonverbal, visuospatial images. Research in cognitive psychology and psycholinguistics has extensively documented the capacity of people to process spatial descriptions and generate visuospatial representations of the situations described (e.g., Denis, 1996; Johnson-Laird, 1996; Mani & Johnson-Laird, 1982). The construction of an internal image from a linguistic description is generally more demanding than is a construction derived from visual inspection of the corresponding object. However, there are strong indications that the internal representations constructed from both kinds of experience have similar structural properties. Moreover, they seem to be accessed by processing mechanisms in quite similar ways (e.g., Denis & Cocude, 1992; Robin & Denis, 1991). The evidence from representational neglect patients, including our own, demonstrates that even in the damaged brain, mental representations derived from perceptual or from linguistic descriptive inputs have similar characteristics[2].

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[2] An intriguing result from the control participants was the suggestion of a mild lateralisation bias in the memory following description condition, with more errors on the left. The phenomenon of pseudoneglect is not new. Most previous studies have reported that controls commit leftward errors (i.e., overestimate the right hemispace) in various bisection tasks (cf. Jewell & McCourt, 2000; McCourt & Garlinghouse, 2000), but may also show right position preference in a range of other activities (e.g., Karev, 2000; Turnbull & McGeorge, 1998). This offers an interesting possible avenue for research on normal cognition, but it is a topic outside the current paper.

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