Unilateral visual neglect overcome by cues implicit in stimulus arrays

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SUMMARY The case of a man with a right hemisphere lesion and with evidence of left-sided visuospatial neglect is reported. On a variety of verbal and nonverbal tasks his performance was significantly modified by information implicit in stimulus configurations. Neglect deficits were present on tests involving spatially distinct or meaningless stimulus arrays but almost absent when stimuli were continuous or meaningfully integrated.

Theories of neglect can be divided into two broad groups which may be referred to as "peripheral" and "central". The former emphasise a deficit in sensory processin: (hemianopia or other somato-sensory/motor impairment) whereby inadequate information is conveyed to one hemisphere. It is widely recognised that such theories do not provide adequate accounts of neglect since sensory deficits are not necessary or sufficient for its manifestation. Central theories of neglect can be subdivided into those focussing on inadequate arousal or distribution of attention and those attributing neglect to faulty central representations of the stimuli themselves. The relative superiority of one central theory over the others is the subject of current debate. However, the problem of weighing their relative merits can be circumvented by taking the view that, rather than being rivals, all these theories have their place in accounting for the multiplicity of neglect phenomena. Indeed neglect may be manifested in a wide variety of forms ranging from "global" to very discrete and task-specific deficits. Patients with global forms of neglect often show not only complete unawareness or inability to respond to all stimuli contralateral to the lesion but their inattention deficits may extend to one half of their own bodies. On the other hand, task specific neglect deficits are by definition under stimulus control and result in multiple fractionations and dissociations. For example, a patient may show neglect at a single word level (neglect dyslexia) but no other type of spatial neglect, even when reading a text. Another patient may present with a right-sided visuospatial neglect but left neglect dyslexia. Recently a further dimension of neglect phenomena has been advanced by Marshall and Halligan in their report on a patient with tacit awareness of left space despite her explicit denial of any stimulus to her corresponding hemifield. The principle underlying the selectivity of neglect in the present case would appear to be different to other cases already documented. Our patient's performance was significantly modified on a variety of verbal and nonverbal tasks by semantic information and plausibly expectations about stimulus configurations. Thus neglect deficits were present on tests that involved spatially distinct stimuli or meaningless stimulus arrays but significantly attenuated when stimuli were continuous or meaningfully integrated.

Case report

A 54 year old right-handed man with VSN was admitted to the National Hospital, Queen Square, on 27 April 1988 for investigations. His symptoms had started 16 years previously. They consisted of intermittent painful sensations in the sacrum area, ascending upwards, as well as his right foot and radiated up to the right hip. Over the previous year or so he had also experienced pins and needles in the cubital fossae of both arms and painful sensations behind his left knee. Examination showed wasting of the left quadriceps and the left ankle jerk was absent. He had a cataract on the right eye but no neuro-ophthalmological abnormality was present. His acuity was satisfactory (right eye 6/12 + 1, left eye 6/5, corrected). CT and MRI scans revealed a mass in the right middle fossa consistent with a meningioma. This appeared to be attached to the greater and lesser wings of the right sphenoid bone with extensive surrounding vasogenic oedema in the right cerebral hemisphere.

At this time his verbal IQ was 103 and his performance IQ was 105 (Wechsler Adult Intelligence Scale) and these
results were in keeping with his estimated optimal level of general ability (National Adult Reading Test\textsuperscript{1}). His verbal memory was a little weak (Recognition Memory Test\textsuperscript{1}) and his performance on certain tests which are sensitive to frontal lobe dysfunction was unsatisfactory (for example, Card Sorting Test, Nelson\textsuperscript{19}).

The patient was operated on in May 1988. A right fronto-temporal craniotomy was performed and the meningioma together with the basal dura, which had been invaded by the tumour, were removed. Post-operatively he suffered a deep vein thrombosis and pulmonary embolism. He developed severe left-sided hemiparesis and dense left homonymous hemianopia with macular sparing. A marked neglect of the left was observed. He was completely unaware of visual stimuli in the left hemispace and, in addition, he showed extinction on double simultaneous stimulation in the tactile domain. Initially he also presented with considerable deviation of his body, particularly the head and eyes, towards the right. At this stage his main complaint was about his poor eyesight. When questioned he realised that his left limbs were paralysed but he showed no concern for his hemiparesis.

On 21 July 1988 the first post-operative neuropsychological assessment was performed. His verbal IQ was 86 and his performance IQ was 57. There was no evidence of a primary dysphasia but he was slow and showed perseveration in his responses. He also presented with a marked left-sided visuo-spatial neglect. He was unable to read a text, completely ignoring the left half of a passage. By contrast, his reading of three-syllable low frequency words was intact and so was his oral spelling. During the following month VSN was assessed repeatedly to analyse his neglect deficits. Gradually his overall condition improved considerably and when he was formally re-assessed on 15 November 1988 his verbal IQ was 95 and his performance IQ was 89.

**Experimental investigations**

The reported data are representative of his performance on a variety of tasks. They were obtained within a period of just over two weeks (26 July to 12 August 1988) and during this time the patient's deficits remained relatively stable. The date each experiment was carried out is given in parentheses. All the experimental investigations took place in the same room. The patient sat in a wheelchair and an adjustable table was placed in front of him. The surface of the table was fixed in a standard position and at a distance of approximately 50 cm from his forehead. All stimuli were presented on the same part (midline) of the table and the patient was allowed to move his head freely. He presented with a marked deviation of his body towards the right but this tendency decreased and during the experimental investigations he began to move his head and eyes while examining the stimuli.

The results are divided into three sections. The first section presents his performance on tests employing discontinuous and relatively meaningless stimuli. The second reports tasks using spatially continuous and meaningfully integrated stimuli. The third section refers to tests of his reading skills.

**A Discontinuous stimulus arrays**

1. **Searching task** (26 July 88). Twenty scattered simple line drawings of common objects\textsuperscript{5} were presented against a 40 cm x 30 cm white background. The patient was asked to point to each object named by the examiner in semi-random order. He was able to locate all the objects with a mean time of 3-5 s for items on the right of the midline and 29-7 s for items on the left of the midline.

2. **Line bisection** (26 July 88). The stimuli consisted of eight horizontal straight lines of different lengths on a page\textsuperscript{25} and the patient was asked to bisect each line in turn. The average mean deviation to the right from the centre was 25 cm (range 3-5 cm to 10-4 cm) or 42% of length of line (excluding two lines on the left of the page that he missed altogether (figure 1). His line bisection a month later, on 28 August 1988, continued to show considerable neglect on the left for this type of stimuli with a mean deviation to the right from the centre of 5-5 cm or 25-9% of line.

3. **Dot counting** (2 August 88). The stimuli consisted of arrays of 5-9 random dots on index cards and arranged with a maximum dispersion of 5-5 cm. The patient was instructed to count the dots on each card. He counted correctly only one out of the ten arrays of dots. He was asked to point to each dot while counting them and it became apparent that his poor performance was due to a neglect phenomenon in that he consistently underestimated the number of dots in the array.

4. **Naming non-interactive, separated silhouettes** (5 August 88). The test consisted of a series of five black silhouettes mounted on white cards on a straight line and at a mean distance of 2-75 mm (range 2-0 mm to 4-0 mm) from each other. The patient was asked to name all the silhouettes on each card (figure 2e). He was able to name the stimuli correctly only in 14/22 cards, thus omitting to report several figures on the left.

5. **Copying geometric designs** (26 July 88). The task required the patient to copy a series of three geometric designs from The Visual Retention Test.\textsuperscript{16} Each stimulus array consisted of two large and one small figure. The patient consistently drew only the figure on the right of each array, regardless of its size (figure 3b). When required to copy only two separated geometric designs his performance was similar (figure 3a).

**B Continuous or meaningfully integrated stimulus arrays**

1. **Shape Discrimination** (2 August 88). The test stimuli consisted of a square (51 mm x 51 mm) and an oblong (6 mm x 46-5 mm) (figure 2d). Ten squares and ten oblongs were
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Fig 2 Example of overlapping, continuous or interactive stimuli (a, b, c, d) which the patient perceived satisfactorily and discontinuous stimuli (e) for which he showed marked neglect on the left.

Fig 3 Copies of the patient's separated geometric designs showing omissions on the left (a, b) and continuous designs which he did satisfactorily (c, d) (models above dotted lines, the patient's copies are below them).

presented singly in random order and the patient's task was to report verbally which shape it was. His performance on this test was remarkably good (17/20).

2 Cube Analysis (2 August 88). This was based on the Stanford-Binet Scale Test (age 11) and consisted of drawings of representations of cubes which were closely arranged in 'two' or 'three' dimensions.²⁹ The number of cubes in each drawing ranged from three to ten (example shown in figure 2b). The patient was asked to indicate the number of cubes depicted and, given his mild visuospatial difficulties, his score on this test was very creditable (8/12). It appeared that only one of his errors was due to omission, the remaining three were accounted for by visuospatial difficulties (he was instructed to point to the cubes while counting them).

3 Overlapping figures (2 August 88). Each stimulus consisted of three overlapping drawings of common objects (Gainotti et al²⁸). The overlap was on the left, right or centre. There were six stimulus configurations, each presented singly, and the patient was asked to describe their contents. His performance was very competent describing 17/18 of the overlapping objects correctly.

4 Interactive Pictures (12 August 88). The stimuli consisted of scenes with two interacting figures.²¹ These pictures were presented on cards either in the original version or with gaps of 20 mm being introduced between the two figures in each scene (figure 2c). The patient was required to describe the contents of each picture. His performance on this test was errorless (12/12).

5 Copying interactive or continuous drawings (26 July 88 and 2 August 88). The patient was asked to copy a variety of interactive/continuous drawings, including designs in
On his way out of the town he had to pass the prison, and as he looked in at the windows, whom should be see but William himself peeping out of the bars, and looking very sad indeed. "Good morning, brother," said Tom, "have you any message for the King of the Golden River?" William ground his teeth with rage, and shook the bars with all his strength; but Tom only laughed at him and advising him to make himself comfortable till he came back again, shouldered his basket, shook the bottle of holy wayside as "quayside"). He also read correctly 9/10 additional, single, handwritten words which were both long and of low frequency (for example, procrastination, belligerently).

3 Sentences (8 August 88). Twenty meaningful sentences, each consisting of seven high frequency words, were constructed. Twenty comparable sentences were also made and rendered meaningless by changing their word order (Appendix 1). Each sentence was typed on a separate card and lower case letters were used throughout, including the initial word of the sentence. The two kinds of sentences were presented in blocks of ten using an ABBA design. The number of sentences read correctly and the errors observed are shown in table 1.

4 Strings of words with various approximations to English (8 August 88). The stimulus material consisted of strings of words of different statistical approximations to English. Ten strings of words of each of three levels of approximation (2, 6, 16) were used (Appendix 1). Each string comprised nine words and was typed entirely in lower case letters on a separate card. The patient was asked to read the different sentence-like series of words in blocks of five using an ABC/BAC design. The number of strings of words read correctly and the number of errors recorded are shown in table 2. (Inspection of the word strings suggests that those with levels of approximation to English 6 and 16 do not differ very significantly in terms of their meaning).

5 Proper names/surnames (2 February 88). The patient was presented with 11 hand written combinations of a forename with a surname (for example, John Brown) and he read all of them without difficulty. (On the one occasion when a redundant extra forename was introduced he failed to read it – John Edward Green was read as Edward Green).

Table 1 Reading meaningful and meaningless sentences: number correct and errors

<table>
<thead>
<tr>
<th></th>
<th>Meaningful</th>
<th>Meaningless</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sentences read correctly</td>
<td>17</td>
<td>7</td>
</tr>
<tr>
<td>Errors:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Omission of words</td>
<td>2</td>
<td>19</td>
</tr>
<tr>
<td>(b) Paralexic</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>
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Table 2  Reading strings of words with various approximations to English: number correct and errors

<table>
<thead>
<tr>
<th>Approximation to English</th>
<th>2</th>
<th>6</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sentences read entirely correctly</td>
<td>2</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Errors:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Omission of words</td>
<td>18</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>(b) Paralexic</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Discussion

The patient, who was right-handed, had dense left homonymous hemianopia and showed evidence of marked visuospatial neglect to the left. But he also presented with other, classical, features of neglect behaviour. These included extinction on double simultaneous stimulation in the tactile domain and marked deviation of his head towards the right despite the weakened musculature on the left of his body. In addition, he showed little concern for his left hemiplegia, that is, he showed 'anosodiaphoria'. The visuospatial neglect deficits shown by this patient are of considerable interest. They appeared to be manifested mainly in the absence of continuity or meaningful integration of stimulus configurations. This formulation derives from a number of dissociations observed in his performance on a wide range of tasks. Specifically, he had difficulty in counting the number of dots in a close random array but at the same time his ability to count the number of cubes represented in continuous two-dimensional drawings was satisfactory. Similarly, although his ability to bisect meaningless straight lines was characterised by gross neglect of the left, he was very competent in discriminating between a square and an oblong which required very accurate perception of the length of the base. The same type of dissociation was observed in his copying skills in that he showed left-sided neglect when stimuli were simple separate geometric figures but he made no omissions when the stimulus was a continuous or overlapping design. For the most part he also underestimated the number of non-interactive separate silhouettes in an array but could describe interactive figures accurately, even when a substantial spatial separation between the two elements in the drawing was introduced. In addition, his identification of overlapping meaningful figures was satisfactory.

Significantly, similar dissociations were observed in his performance on reading tasks. In spite of the fact that paralexic errors affecting the beginnings of words is common in patients presenting with gross neglect, the patient showed no evidence of neglect dyslexia. Arguably, the constituent strings of letters of even compound words provide an integrative type of stimulus in the sense that a word as a whole has a distinctive meaning. In contrast, his prose reading was very impaired. Continuous text words in the right hemifield (to which his attention was invariably first drawn) may appear as a "random" set and therefore act as non-integrative and meaningless stimulus array. When we subsequently attempted to manipulate the degree of randomness of words by using meaningful and non-meaningful sentences or reading material with different approximations to English, the results were consistent with those of the earlier experiments; that is, the greater the meaningfulness of the word strings the fewer word omissions were observed.

The question arises whether the patient's left-sided neglect for discontinuous and/or meaningless stimuli could have been due to a failure to compensate for his left dense hemianopia. The main evidence against this argument is his good performance on tasks which, from a purely 'sensory' point of view, are far more difficult than other tasks in which he failed. Thus he described entirely satisfactorily interactive figures with substantial gaps between them but he had difficulty in perceiving non-interactive silhouettes with much smaller gaps between them. Further evidence against an explanation of his neglect deficits in terms of a faulty sensory input is provided by the results of the tests in which the meaningfulness of the reading material was manipulated. Clearly the dissociation in his performance with the meaningful and meaningless material could not have been predicted by a purely sensory explanation of his neglect deficits.

Can "central" theories of neglect account for the observed phenomena? First, we considered the theory by Bisiach et al which argues that neglect is caused by an inability to construct or assess adequately visual representations of stimuli. This theory has been very influential and seems to account for a wide range of neglect phenomena in external space (for example, copying of a drawing) as well as internal space (for example, imagery tasks). However, contrary to the theory put forward by Bisiach et al the patient's performance across tasks suggested integrity in his constructions of internal representations of stimuli. For example, not only was he able to perceive readily a wide range of meaningful stimulus configurations but he could also draw satisfactorily without a model.

Other influential central theories of neglect include those of Kinsbourne and Posner et al. Their arguments centre on the notions that inhibition of one hemisphere (due to damage) results in the other hemisphere's bias towards, or a disorder of, 'disengagement' of attention from the ipsilateral hemisphere. Our data indicate that our patient with VSN did indeed show considerable bias of his attention for the right hemisphere as shown by his performance on, for example, the searching task. However, the data also
show a substantial degree of disengagement of the patient's attention from his good (right) hemifield but mainly under certain conditions; that is, when stimuli appeared to provide sufficient cues about their own extension or their meaningful integration with other stimuli in the left hemifield.

The effects of cues on neglect have been explored by other investigators and there have been reports suggesting that unilateral neglect can be reduced when patients are forced to attend to a cue contralateral to their lesion. For example, Riddoch and Humphreys found a substantial decrease in neglect on line bisection tasks when patients were cued and instructed to report stimuli in their neglected hemifield. In experiments by Posner et al., the effects of 'cuing' on simple reaction time tasks (RTs) in patients with unilateral parietal lesions were also studied. They found that when the position of a visual target was preceded by a cue on the same side of fixation (termed valid cue) there were relatively small differences in RTs to targets presented contralaterally or ipsilaterally. However, when the target was presented on the opposite side of fixation to the cue (termed non-valid cue) the RTs were substantially slower for targets contralateral to the sites of lesion. These experiments therefore provided further evidence suggesting that with valid cues patients with unilateral neglect may be able to shift attention to the contralateral hemifield. The work of Posner et al. specifically attempted to delineate the effects of cueing on 'overt' attention. This latter term refers to mechanisms involving central attentional systems as opposed to 'overt' attention which is mediated by eye movements, postural changes, etc. In the case of our patient it is reasonable to assume that the central attentional systems interacted with overt systems since the tasks which were administered were not subject to tight time constraints. However, his performance could be construed as analogous to that of the patients of Posner et al., in the sense that meaningful/integrated stimuli appeared to act as valid cues and non-meaningful/non-integrated stimuli appeared to act as non-valid cues. Here we would argue that the patient was 'guided' towards the left hemifield by attention directing stimuli provided by the information available in his good hemifield. Thus the shift of his attention to the contralateral hemifield was entirely dependent on cues implicit in the stimulus configurations themselves rather than experimental instructions or other externally provided cues. To our knowledge such an observation has not been previously documented.

This formulation leads to a postulation of a type of neglect in which disengagement of a patient's attention from his ipsilateral hemifield to the contralateral hemifield can be achieved on the basis of cues and an interpretation of the information present in his good hemispace. An active process of this type would require a 'comparator' in which the information initially perceived on the non-affected hemispace is matched to central stored representations of stimuli. The comparator would then modulate a patient's searching behaviour so that whole familiar objects and units of verbal material, including 'chunks' of meaningful strings of words, can be processed.

The range of impairments which are grouped under the concept of neglect clearly constitutes a heterogeneous class of deficits. It is also widely recognised that a wide variety of brain structures seems to underlie neglect phenomena and, to date, the knowledge on the precise mechanisms involved in different types of neglect is limited. It would be premature to speculate on the neural substrates of the neglect phenomenon reported here.

We thank Drs R S Kocen and P C Gautier-Smith for permission to investigate the patient with VSN and report our findings. We also thank Jane McNeil for her help with the preparation of the figures.

Appendix

Meaningful Sentences
1. dogs have a good sense of smell
2. he sent the letter without a stamp
3. tourists have a good time in London
4. dogs cannot chase cats up the trees
5. pies have always a very delicious taste
6. she locked the money in the safe
7. children are usually afraid of the dark
8. boys prefer to play with older children
9. she swept the floor with a brush
10. she cleaned the dirt from her hand
11. they lay down and went to sleep
12. we could not remember all the names
13. he washed his face and changed clothes
14. she wanted to perform the same act
15. men prefer short-sleeve shirts in summer
16. gardens are well kept by our neighbours
17. men shave their faces with electric razors
18. father and son love each other's company
19. mothers prefer old remedies for their babies
20. actors like being interviewed by radio reporters

Meaningless Sentences
1. nail drove the boy into the wood
2. whip hit the horse with the man
3. scarf loosened the girl around her neck
4. floor swept the woman with a brush
5. cans of beer dropped down the men
6. bell rung the girl on the door
7. all plates placed she on the table
8. silk shirts like to iron the women
9. flowers came down to cut the man
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Word strings with different approximations to English (2, 6, 16)

(2)
1 the camera shop and boyhood friend from fish and
2 screamed loudly men only when seen again and then
3 in the tree is idiotic idea of almost there
4 cabbage a horse which was not always be set
5 sideways chewing toffee stuck around about it with door
6 every cat eats his bicycle chain mail of teacher
7 travel in case you must go to dance sideways
8 straight on the rat tail of many people are
9 the cat sat door married in the essential for
10 words every evening is heaviest with bovine eyes on

(6)
1 lots of time for studying and praying to God
2 living according to common ideas as she had said
3 painting which is hanging on our most precious line
4 small villages are where everyone is concerned about the
5 parties at home are successful beyond words and help
6 messages to interpret correctly and with every good script
7 translations of speeches given by one man without words
8 standing as still as any rock upon a hillside
9 there were several people jumping about in the chair
10 screaming aloud and giving way to many suppressed lines

(16)
1 the very next day they went for a picnic
2 woods were not really suitable for them to visit
3 they saw bulls in the field which might attack
4 girls were not there to cause any major trouble
5 no harm whatever will come from their new ideas
6 they flee all possible dangers from the cruel sea
7 since they completed their long rounds they left home
8 they began on work which was left poorly done
9 they played at bowls like Drake on Plymouth Hoe
10 before the arrival of the ship he had left

References
1 Brain R. Visual disorientation with special reference to the lesions of the right cerebral hemisphere. Brain 1941;64:244–72.