
Visual and Tactile Size Distortion in a Patient with Right Neglect

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Abstract

One typical feature of the neglect syndrome in patients with right hemisphere damage is that they bisect horizontal lines to the right of centre. It has been argued that to a large extent these bisection errors can be attributed to a perceptual change whereby the patient experiences the left half of a line as shorter than the right half, causing them to set the midpoint of the line towards the right. We describe here a patient with a left hemisphere lesion and rightward neglect, who consequently makes bisection errors in a leftward direction. We carried out a series of tests which confirmed that he shows a subjective visual distortion in the converse direction, i.e. a perception of horizontal extents on the right as shorter than extents on the left. We also found that he shows a similar distortion in his tactile perception. The association of visual and tactile distortions in this patient is compatible with the view that the distortion effects have a rather high-level origin. Multiple single-case studies will, however, be required to establish whether this association of deficits is typical, or whether visual and tactile size distortions are separable symptoms associated with neglect.

Introduction

It has been proposed in previous papers that many right hemisphere-damaged patients with neglect, mark lines to the right of centre in the standard bisection task due to a misperception of the lines (Milner, 1987; Harvey *et al.*, 1995). This was demonstrated directly by presenting patients with a series of already transected lines, many of which were transected at the precise midpoint. It was found that when asked to point to the end of the line nearer to the transection mark (the so-called 'landmark'), most neglect patients pointed predominantly to the left, in some cases even when the line was actually pre-transected 1 or 2 cm to the right of centre (Milner *et al.*, 1993; Harvey *et al.*, 1995; see also Bisiach *et al.*, 1998a). In a similar vein, when patients were asked to extend a line on paper to twice its length, they tended to over-extend it when drawing leftwards, but under-extend rightwards (Bisiach *et al.*, 1996, 1998b; Chokron *et al.*, 1997). In both tasks, such leftward responding requires patients to go against any neglect-induced pre-motor bias to respond rightwards ('directional hypokinesia'; Heilman *et al.*, 1985). Indeed, there are comparatively few patients who respond predominantly rightwards in the landmark task, so this factor appears to play a relatively minor role in determining the bisection errors of typical neglect patients.

The perceptual errors observed in the landmark task can also be seen in tasks where the patient is asked to compare two separate lines or rectangles presented side by side on a television screen (Milner and Harvey, 1995; Irving-Bell *et al.*, 1999; Kerkhoff, 2000), or on paper (Milner *et al.*, 1998). Typically a neglect patient will perceive two horizontal lines or rectangles as of equal length only when the leftward of the two is actually some 10–15% longer than the one on the right. Recent research indicates that the biases seen in both this size-matching task (Ferber and Karnath, 2001) and in the line-extension task (Doricchi and Angelelli, 1999) are strongly associated with posterior lesions and with the presence of visual field defects.

A small number of patients with left hemisphere lesions exhibit right visuospatial neglect. Right neglect following left hemisphere damage is less common, and typically less persistent than left neglect following right hemisphere damage (e.g. Halligan and Marshall, 1995). However, we describe here a patient who suffered from severe right visuospatial neglect for several months after a left hemisphere stroke. We report evidence for consistent perceptual size underestimation of stimuli presented on the right and further demonstrate that this effect can be observed for tactile as well as for visual stimuli.

Table 1. DL's performance on six subtests of the WAIS-R. Scaled scores, with age-adjusted scores in parentheses

| Verbal subtests | | | Performance subtests | | |
|-----------------|------------|------------|----------------------|--------------|-----------------|
| Information | Digit span | Vocabulary | Picture completion | Block design | Object assembly |
| 6 (7) | 5 (6) | 9 (10) | 6 (9) | 4 (6) | 5 (8) |

WAIS-R, Wechsler Adult Intelligence Scale-Revised.

Table 2. DL's performance on the six conventional subtests of the Behavioural Inattention Test (*right neglect)

| Line crossing | Letter cancellation | Star cancellation | Figure and shape copying | Line bisection | Representational drawing |
|---------------|---------------------|-------------------|--------------------------|----------------|--------------------------|
| 17/36* | 4/40* | 13/54* | 1/4* | 0/9* | 2/3* |

Methods

Subject

DL, a 64-year-old man, sustained an ischaemic stroke of the left hemisphere in May 1998 resulting in right hemiplegia and right homonymous hemianopia to confrontation. A computed tomography (CT) examination performed 9 days later revealed a massive infarct in the territory of the left middle cerebral artery, affecting the frontal lobe and most of the parietal lobe and associated deep structures. The occipital lobe was entirely spared, and the temporal cortex largely (although not entirely) spared. Formal assessment of DL's visual fields was performed by Humphrey perimetry in June 1999. This confirmed that his right hemianopia was complete and homonymous. The tests reported here were conducted during the second month post-stroke, with DL's informed consent. All manual responses were made using the unaffected left arm.

DL was left-handed by self-report and expressed a left hand preference for 10 of 12 items on the Annett Handedness Questionnaire. He was dysarthric but exhibited no signs of aphasia in his spontaneous speech or in formal testing (only two misspelling errors on the Short Minnesota Aphasia Test). DL performed within normal limits on three verbal and three performance subtests of the Wechsler Adult Intelligence Scale-Revised (WAIS-R; Table 1). On the Benton Visual Form Discrimination Test, he scored 26 (a score of 25 or below indicates defective performance). His pre-morbid full-scale IQ was estimated at 100 [National Adult Reading Test (NART)].

Administration of the six conventional subtests of the Behavioural Inattention Test confirmed the presence of severe right visual neglect (total score = 37/146; cut-off = 129), with neglect identified on every subtest (see Table 2). A number of additional tests were carried out to characterize further the nature of DL's neglect impairment.

Materials and methods

Bisection. Following the method of Milner *et al.* (1993), DL bisected 36 black 20 cm horizontal lines presented horizontally and centrally on white sheets of A4 paper, with 12 lines per sheet. One sheet was presented at each of three locations with respect to the body midline: with the sheet symmetrically straddling the body midline or with its centre displaced 30 cm into left or right hemisphere. On each sheet, three lines were presented in each of four cueing conditions: no cue, with a capital letter adjacent to the left end of the line, with a capital letter adjacent to the right end of the line or with capital letters adjacent to both line ends. For each letter that was present, DL was required to report its identity prior to placing his transection mark. DL was instructed to bisect each line centrally, using his left hand, proceeding line by line down the sheet. After each transection, that line was covered with a white card in order to prevent comparison of the present response with previous responses. The order of presentation for the spatial location condition was right, left, centre. On each sheet of 12 lines, the order of cueing condition was pseudo-randomized.

Landmark task. Following the method of Milner *et al.* (1993), DL was presented with three series of 22 black 20 cm horizontal lines presented individually on white sheets of A4 paper. Each line had been pre-transected at right angles with a 'landmark' line 10 mm in length. Of the 22 lines, 10 were asymmetrically transected (1, 2, 3, 4 or 5 mm to the right or left of centre). These asymmetrical stimuli were uncued, and served as 'fillers' to encourage the impression that all 22 lines might be asymmetrically transected. The remaining 12 lines were pre-transected at the objective midpoint, and three were presented in each of the four cueing conditions described for the bisection task. In each trial, DL was required to make a forced-choice discrimination, pointing to the end of the

line that he judged to be closer to the transection mark. The total set of 22 lines was presented once in each of three spatial locations (as described for the bisection task). Spatial location was blocked (centre, left, right) and the stimulus order was randomized within each block.

Visual size matching (line drawings). In this task, DL made relative size judgements regarding lateralized pairs of horizontal lines, unfilled horizontal rectangles, circles and radial ('vertical') lines. Stimulus pairs were printed in black on white sheets of A4 paper presented at the body midline so that one stimulus lay to either side of the midline. Sixteen trials were presented for each stimulus type with stimulus type blocked (vertical lines, horizontal rectangles, circles, horizontal lines). In every trial a standard stimulus (8 cm in length or diameter) appeared in at least one of the two positions. Within each block of 16 trials, the standard stimulus was paired with a smaller stimulus on the left (7.8, 7.6, 7.4, 7.2 or 7.0 cm) on five occasions and with a smaller stimulus on the right on five occasions. In the remaining six trials, standard stimuli were presented on both sides of the sheet. The stimulus order was randomized within each block of 16 trials. In every trial, DL was required to make a forced-choice discrimination, indicating verbally which stimulus he considered to be the smaller of the two.

Visual and tactile size matching (solid objects). In this task, DL made relative size judgements about the horizontal extent of solid rectangular objects which were either visually inspected, or haptically explored whilst blindfolded. Four rectangular objects made of grey plastic were used. All objects were 1.0 cm high and 1.0 cm wide, and were fitted with pins to fix them in position on a 30 cm square board of the same grey plastic. The board was placed directly in front of the subject's body midline. In each trial, two objects were presented centred 15 cm from the edge of the board on the subject's side and displaced 7.5 cm to the left and right of the midline. For visual discriminations, DL was allowed unlimited viewing time. For tactile judgements, he was blindfolded and had his left index finger placed on a starting position equidistant from the two objects. The objects had to be explored using the index finger only, but they could be explored in any order and as many times as desired. In both conditions, DL indicated his response by pointing to the object that he believed to be smaller (or larger, see later).

In every trial, a standard stimulus (4.0 cm in horizontal length) was placed in at least one of the two positions. Four trial blocks were performed with 24 trials in each block following eight initial practice trials. Within each block of 24 trials the standard stimulus was paired with a smaller stimulus on the left (3.5, 3.0, 2.5 cm long) on six occasions, and with a smaller stimulus on the right on six occasions. In the remaining 12 trials, standard stimuli were presented on both sides of the board. The stimulus order was randomized within each block of trials. In every trial, DL was required to make a forced-choice size discrimination, which was

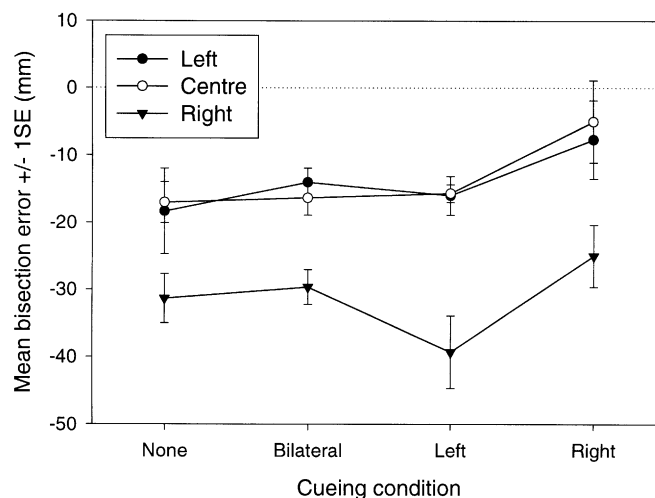


Fig. 1. DL's mean leftward line bisection errors as a function of spatial location and cueing condition (negative is left).

indicated verbally. Stimulus modality was blocked in an ABBA design beginning with visual presentation. The precise discrimination required ('which is longer' or 'which is shorter') was blocked in an AABB design beginning with 'shorter' judgements.

Results

Line bisection task

As shown in Fig. 1, DL made large leftward bisection errors (mean error = -19.6 mm, SE = 1.9). A two-way ANOVA by spatial location and cueing condition revealed significant main effects for both factors (cue: $F_{(3, 24)} = 4.1$, $P < 0.05$; space: $F_{(2, 24)} = 23.3$, $P < 0.001$) and no significant interaction. Bonferroni post-hoc analysis of the cueing effect revealed that a right-sided cue reduced the extent of DL's leftward errors compared with a left-sided cue ($P < 0.05$); none of the other cueing conditions differed from one another. Bonferroni post-hoc analysis of the spatial location effect found that DL made reliably larger leftward errors for lines presented in right hemispace than for lines at central or leftward locations ($P < 0.0005$ in both cases).

Landmark task

When presented with centrally pre-transected lines, DL indicated that the right half of the line appeared to be shorter in every single trial (precluding analysis of the effects of spatial location and cueing condition). Indeed, even when the landmark was situated to the left of the midline, he indicated that the rightward portion was shorter in 13/15 trials. Amongst 12 age-matched controls tested on the same task, none judged the right half of the centrally transected lines to be shorter in more than 64% of trials. It should also be noted that DL pointed accurately to the right-hand end of each line when indicating that this lay closer to the transection

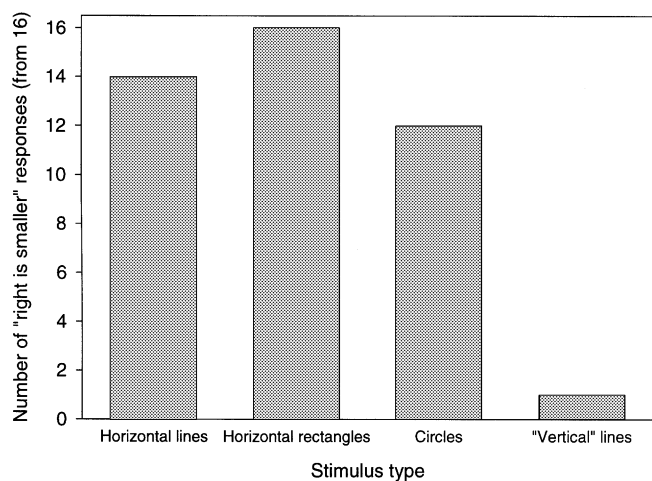


Fig. 2. The number of 'right is smaller' responses (from 16) made by DL when judging the relative size of horizontal lines, (unfilled) horizontal rectangles, circles and 'vertical' lines printed on paper.

mark. His rightward underestimation cannot therefore have been due to a failure to explore the whole of the line.

Visual size matching (line drawings)

As shown in Fig. 2, DL judged horizontal lines, horizontal rectangles and circles presented to the right to be smaller than those presented to the left ($P < 0.05$, binomial test for each of the three stimulus types). This was not the case for vertical lines ($P < 0.05$, binomial test, in the opposite direction).

In order to check that DL's underestimation of rightward horizontal extents was not due simply to a failure to fixate far enough rightwards, the horizontal line trials were repeated with the instruction that DL should place a pencil mark at both ends of each line (this was done after he had indicated which of the lines appeared shorter). DL judged the right line to be shorter in all of 16 trials. He was also able to mark both ends of each line accurately and without any help, indicating that he could indeed explore visually the whole of each line. Occasionally, after DL had placed his pencil marks, he was again asked to say which stimulus appeared shorter. In no such trial did DL reverse his original judgement that the right stimulus was the shorter.

Visual and tactile size matching (solid objects)

The total number of trials in which the right object was judged to be smaller (or the left object to be larger) was 35/48 and 36/48 for visual and tactile presentations, respectively (binomial test, $P < 0.001$ in both cases). DL thus perceived the rightmost object to be smaller than the left significantly more often than vice versa, irrespective of the modality of stimulus presentation.

Discussion

This study reports a case of right neglect following left hemisphere damage in a left-handed man. Patient DL is

unusual in exhibiting severe and persistent neglect following a left hemisphere lesion (Halligan and Marshall, 1995). He is also remarkable for having developed no detectable language impairments despite an extensive left hemisphere infarct that affected most of the parietal lobe. This latter fact suggests that the normal left hemisphere dominance for speech and language may have been reversed in this patient, a pattern that is estimated to be present in about 15% of the left-handed population (Rasmussen and Milner, 1976). If this is the case, then it is possible that DL's impaired spatial awareness does not represent a specifically left hemisphere variety of neglect, but a relatively typical right hemisphere pattern expressed in mirror image form due to reversed cerebral dominance.

The notion that DL might represent a 'mirror image' of a left neglect patient is consistent with the typicality of his impairments across a range of tasks. DL demonstrated neglect on each of the conventional subtests of the Behavioural Inattention Test and his line bisection errors were influenced by overt cueing and by manipulations of spatial location (cf. Riddoch and Humphreys, 1983). Moreover, the data from five tasks (line bisection, landmark, pictorial size matching, tactile and visual object size matching) indicate a pronounced rightward size underestimation in DL. The magnitude of this effect is comparable with the leftward size underestimation previously reported in right brain-damaged patients with left neglect, using identical tasks (Milner *et al.*, 1993, 1998; Harvey *et al.*, 1995; Milner and Harvey, 1995).

These findings are consistent with the idea that underestimation of the size of objects on the neglected side is an integral part of the neglect syndrome. At the same time, it is important to note that DL suffered from a right field hemianopia, so that our data are consistent with those reported more recently by Doricchi and Angelelli (1999) and Ferber and Karnath (2001). That is, we may suppose that DL's lesion placed him in a category of neglect patients particularly prone to experiencing a distorted perception of visual size. But is the visual field defect typically seen in neglect patients who show size distortion the cause of that distortion, or just a correlate of it, both symptoms being due to the posterior location of the brain damage? That is, is the size distortion in neglect a simple consequence of a rather low-level visual loss? That such distortion certainly can occur as a result of damage that causes hemianopia but not neglect, seems clear from the results of Ferber and Karnath (2001). This does not, however, imply that the distortion is caused by the hemianopia. Even without neglect, there may be damage to higher visual areas as well as to early visual cortex (V1 and/or V2/V3), and it could be the former damage rather than the latter that causes the distortion.

Our data showing DL's distorted perception of tactile as well as visual size offer a new perspective on the causes of this relationship between visual field defects and perceptual abnormality. In particular, they offer support for the view of Bisiach *et al.* (1996), who suggested that in neglect patients 'the left-right dimension of space representation is settled,

as it were, on a logarithmic scale, with compression on the ipsilesional side and expansion on the contralesional'. That is, the present data are consistent with the notion that incoming sensory stimulation is projected on to a supramodal cerebral substrate for space representation that has been distorted due to posterior brain damage. In contrast, if incoming visual information was itself distorted and interpreted as such by an unbiased spatial processor [as implicitly assumed by Milner (1987)], then tactile distortion would not necessarily be expected to be present.

Of course, the spatial processor that has been damaged by the lesion need not be truly supramodal. The objects we used in the tactile matching task, had, after all, been observed during visual size matching by the patient before he was blindfolded. Presumably, therefore, he would have had little trouble in forming a visual image of the apparatus and of the rectangular blocks used, even when only receiving tactile information about them. It is quite possible, in other words, that the typical strategy used (by healthy as well as brain-damaged people) in our tactile matching task is to transform the input from each object into a visual image, and to compare implicitly two such visual images. The size distortion would then operate on the visual representation, just as neglect itself can operate imaginatively in many patients (Bisiach and Luzzatti, 1978; Bisiach *et al.*, 1979), causing the apparent 'tactile' size distortion.

On the other hand, we must be mindful of the fact that the co-occurrence of visual and tactile size distortion in a single patient does not necessitate shared functional causality between the two deficits. It is possible that they represent separable impairments that, in this patient, happen to co-occur. The relationship between visual and tactile size underestimation might thus be similar to that found between visual and tactile neglect for search tasks. An early group study observed an association between left-sided omissions in visual and tactile search and hypothesized a supramodal disorder of spatial awareness to explain this association (De Renzi *et al.*, 1970). However, subsequent multiple single-case studies have demonstrated that the two symptoms are in fact doubly dissociable (Barbieri and De Renzi, 1989; Cubelli *et al.*, 1991). Similar multiple single-case analyses will be required to determine the nature of the relationship between visual and tactile size distortion. The present study provides a starting point for these investigations by establishing the existence of tactile size distortion in neglect, comparable in nature to the visual distortions that many patients exhibit.

Conclusions

We conclude from this single-case study that right-sided neglect caused by a left hemisphere lesion can cause visual size distortions equal and opposite to those often seen in patients with left-sided neglect. Furthermore, the visual size misperception seen in our patient was mirrored by a similar degree of tactile size misperception. We conclude that the

patient was unlikely to have been experiencing merely the perceptual consequences of damage to low-level visual cortex. Our data demonstrate the existence of tactile size distortion in neglect and highlight the possibility that this may result from a disordered supramodal spatial representation, or from a rather high-level visuospatial disorder affecting visual imagery.

Acknowledgements

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Abstract

One typical feature of the neglect syndrome in patients with right hemisphere damage is that they bisect horizontal lines to the right of centre. It has been argued that to a large extent these bisection errors can be attributed to a perceptual change whereby the patient experiences the left half of a line as shorter than the right half, causing them to set the midpoint of the line towards the right. We describe here a patient with a left hemisphere lesion and rightward neglect, who consequently makes bisection errors in a leftward direction. We carried out a series of tests which confirmed that he shows a subjective visual distortion in the converse direction, i.e. a perception of horizontal extents on the right as shorter than extents on the left. We also found that he shows a similar distortion in his tactile perception. The association of visual and tactile distortions in this patient is compatible with the view that the distortion effects have a rather high-level origin. Multiple single-case studies will, however, be required to establish whether this association of deficits is typical, or whether visual and tactile size distortions are separable symptoms associated with neglect.

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Primary diagnosis of interest

Right-sided unilateral neglect

Author's designation of case

DL

Key theoretical issue

● Contralateral size underestimation is observed for horizontal extents presented in both visual and tactile modalities. This report provides a novel existence proof of tactile size underestimation. The observed association of deficits further suggests the possibility of a high-level supramodal disorder of spatial representation

Key words: perception; distortion; neglect; size; tactile; visual

Scan, EEG and related measures

Computed tomography

Standardized assessment

Annett Handedness Questionnaire, Benton Visual Form Discrimination, Behavioural Inattention Test (six conventional subtests), Humphrey Perimetry, National Adult Reading Test (NART), Short Minnesota Aphasia Test, Wechsler Adult Intelligence Scale-Revised (WAIS-R; three verbal and three performance subtests)

Other assessment

Landmark task, line bisection, tactile size matching, visual size matching

Lesion location

● Left middle cerebral artery territory: frontal, temporal, parietal

Lesion type

Ischaemic infarct

Language

English