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CASE STUDY

Three-dimensional neglect phenomena following right anterior choroidal artery infarction

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Abstract

Neglect in the horizontal and vertical axes of space has been observed after acute right anterior choroidal artery (AChA) lesions. How spatial processing is affected in the radial axis during the acute period following infarction in this region is unknown. We report the case of a 69-year-old man with acute left hemineglect and deficits in 3-dimensional spatial processing following right AChA infarction. His line bisections in 4 spatial conditions, oriented in the 3 primary axes of space, were compared with 6 control participants. The patient's bisections were different from true center and from control performance in all axes. His bisections were to the right, below, and distal to the arithmetic midpoint. This patient's bisection errors show a 3-dimensional neglect pattern following right AChA infarction, supporting the view that processing of all 3 spatial dimensions may be simultaneously disturbed following unilateral right hemisphere lesions. (*JINS*, 1999, *5*, 567–571.)

Keywords: Neglect, Line bisection, Anterior choroidal

INTRODUCTION

Neglect is characterized by impaired ability to respond to, orient toward, or act upon stimuli occurring in a circumscribed region of space, usually opposite an acute cerebral hemispheric lesion (Heilman et al., 1993). Historically, neglect has been studied as a left–right dichotomized phenomenon of attention, arousal, intention, or related constructs, but more recent work has shown disorders of attentional allocation along the vertical and radial axes of space as well (Rapcsak et al., 1988; Shelton et al., 1990). When specifically tested, disordered processing along these axes may also be found in otherwise typical cases of left hemispatial neglect. Thus, patients with unilateral parietal lobe lesions often misbisect vertically oriented lines above their true center (Bender & Teuber, 1948), and radially oriented lines distal to their midpoint (Halligan & Marshall, 1993; Marshall & Halligan, 1990).

Far peripersonal and vertical neglect was originally demonstrated in patients with bilateral hemispheric lesions (Shelton et al., 1990). Mennemeier et al. (1992) later suggested that bilateral lesions might magnify the effects of disordered processing in the vertical and radial of space. They predicted that these deficits might be found in cases with unilateral lesions. Indeed, Kageyama and coworkers subsequently reported neglect in three dimensions among many patients with unilateral cerebral lesions (Kageyama et al., 1994).

Right parietal cortical lesions are perhaps the most commonly recognized cause of neglect syndromes, but subcortical lesions in the right hemisphere can also produce left-sided neglect (Ferro et al., 1987; Ferro & Kertesz, 1984; Healton et al., 1982; Sakashita, 1991; Watson et al., 1981). Unilateral spatial neglect is a remarkable feature of the right anterior choroidal artery (AChA) syndrome (Bogousslavsky et al., 1988; Decroix et al., 1986; Heaglson et al., 1986), which typically occurs when AChA strokes involve the posterior limb of the internal capsule (Hupperts et al., 1994).

Such deep hemispheric lesions also appear to have effects on three-dimensional spatial processing. For example, neglect in the horizontal and radial axes has been observed with lesions of the posterior limb of the internal capsule and thalamus (Marshall & Halligan, 1995) and in the horizontal and vertical axes following an AChA infarct (de la Sayette et al., 1995).

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Line bisection tests have been used to identify neglect, as well as characterize attentional biases in normal individuals. Performance on a line bisection task allows examination of spatial processing along a single axis of space. Inaccurate bisection reflects a failure to attend to a portion of the line, an attentional bias toward the opposite extent, or an inability to direct action toward a portion of the stimulus or its surrounding space (intention). Bisection of lines arrayed in different axes can also be used to infer performance biases in three dimensions of space. Neurologically intact subjects often misbisect lines oriented along the horizontal (left–right) axis to the left of true center (Bowers & Heilman, 1980; Mennemeier et al., 1992; Shelton et al., 1990). Other reports have not identified this pattern (Halligan & Marshall, 1993; Manning et al., 1990). Significant interindividual or task factors that influence performance of horizontal line bisections may account for the differing results on this task (Manning et al., 1990). Nonetheless, vertically oriented lines are usually bisected above true center (Scarisbrick et al., 1987). Lines oriented radially away from the body in the midsagittal plane and located below eye level are typically bisected distant to the arithmetic midpoint (Geldmacher & Heilman, 1994; Halligan & Marshall, 1993; Shelton et al., 1990). The syndrome of altitudinal neglect suggested that stimuli positioned high in the spatial representation may be processed differently from lower ones (Rapcsak et al., 1988). Indeed, there is evidence that radially oriented lines presented above eye-level are bisected more proximally than identical lines presented at usual desktop levels (Geldmacher & Heilman, 1994).

We report a patient with a multidimensional neglect syndrome following AChA distribution infarction. We review the pertinent features of current conceptual approaches to neglect and discuss the possible mechanisms of neglect in our patient in this context.

CASE HISTORY

A 69-year-old right-handed man acutely developed difficulty driving and left sided weakness. On examination he had marked left facial weakness that spared the forehead (i.e., an upper motor neuron pattern) and less severe left hemiparesis. Deep tendon reflexes were brisk on the left. Plantar responses were flexor on the right and extensor on the left. Perception of tactile stimulation was decreased on the left side and extinction to double simultaneous stimulation was present. He was aware of, and concerned about, his deficits. He was easily tearful when his impairments were reviewed. During his acute hospitalization, he was observed to have typical signs of neglect. For example, he ate food only from the right side of his plate and oriented to the right when addressed from his left.

Clock drawing was normal. Several versions of random-array letter cancellation tests did not reveal an increased tendency to omit targets toward the left. He did, however, demonstrate an atypical search pattern on the cancellation tasks, moving from right to left, rather than the more common left-to-right direction. Goldmann visual perimetry showed a left homonymous congruent field defect, with the superior quadrants more affected. Magnetic resonance imaging of the head showed an infarction in the caudal two-thirds of the posterior limb of the right internal capsule extending into the tip of the mesial temporal lobe, the medial tip of the lentiform nucleus, anterior thalamus, and mesencephalon. This lesion follows the distribution of the anterior choroidal artery (Figure 1).

LINE BISECTION STUDIES

Control Participants

In addition to the patient, line bisections were obtained from 6 right-handed, neurologically intact, men and women ages 57 to 72. Control participants were recruited from a research registry of healthy older adults. The patient and three controls bisected 25.0-cm lines. As a part of their participation in other studies, bisections were available for 23.5-cm lines for the other 3 healthy controls. Previous studies have shown no effect of line length on bisection between 20 and 30 cm (Geldmacher & Heilman, 1994; Kageyama et al., 1994; Shelton et al., 1990).

Procedure

The patient was tested in his hospital room, seated at the side of the bed, on the 3rd day following the onset of symp-

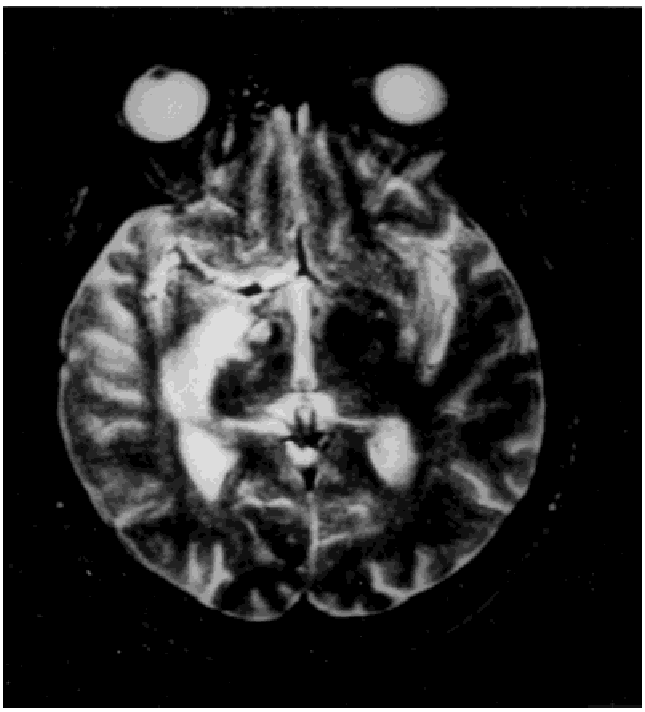

Fig. 1. MRI findings. Axial T2 section of the patient, showing hyperintense signal changes in the right posterior limb of the internal capsule and anterior thalamus.

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toms. Controls were tested in an outpatient clinical research setting.

Black line segments were presented on 21.6 × 27.9 cm white paper. Bisections were tested in four spatial conditions: (1) horizontal (right–left), (2) vertical (up–down), (3) radial (near–far) above eye level, and (4) radial below eye-level conditions. Control participants were also tested in the seated position. Five lines were bisected in each spatial condition. Bisection stimuli were presented in blocks of five trials, such that all lines of one orientation were administered consecutively before moving to the next orientation. Stimulus sheets were centered approximately 30 cm from the subject in the midsagittal plane. The vertical distance between eye level and stimulus sheet was approximately 40 cm in all below and above eye-level conditions. Vertical lines were centered about 10 cm below eye level.

Data Collection and Analysis

All participants were instructed to mark the center of the line as accurately as possible and bisections were measured to the nearest 1 mm. Since two different line lengths were used, all errors were calculated as percentage of total line length. Arbitrarily, a positive value was assigned to bisections to the right of, above, and distant to true center. Following the previously reported method of Geldmacher and Heilman (1994), 95% confidence intervals were used to determine whether the line bisection errors were different from true center. Student's *t* tests for unpaired samples were used to identify differences in mean bisection error between cases and the control group.

RESULTS

The patient showed a consistent directional preference in his line bisections (Table 1). He bisected horizontal lines to the right of the true center in five of five trials. Vertical lines were bisected below true center in four of five trials. Bisection errors on radial lines above and below eye level were distant from true center in four of five trials for each condition. Bisection errors were more pronounced in the radial above-eye condition than in the below-eye condition and the least pronounced effects were seen in the vertical condition.

The 95% confidence interval for the patient's bisections differed from arithmetic center in all conditions (Table 1). When compared by *t* tests for unpaired samples, line bisections were significantly different between the patient and the control group in all conditions. In the horizontal plane the patient's mean error was 17% of line length and mean control error was zero percent ($t = 4.88$, $p < .005$). For bisections in the vertical plane, the mean errors were 4% for the patient and zero percent for controls ($t = -2.26$, $p < .05$). Mean errors on radial bisections below eye level were 8% of line length for the patient and zero percent for controls ($t = 2.72$, $p < .03$). For bisections in the radial plane above eye level, mean patient error was 20%; it was zero percent for controls ($t = 2.49$, $p < .04$).

DISCUSSION

Our patient presented evidence of neglect phenomena in three dimensions on line bisection testing following infarction in the typical distribution of the right AChA, including the posterior limb of the internal capsule (de la Sayette et al., 1995; Hupperts et al., 1994). There was a floridly evident left hemineglect syndrome, but the errors on the line bisection also indicate impaired spatial processing consistent with subtle neglect of upper space and near peripersonal space. This pattern is different than the combined superior–distant neglect reported by Shelton et al. (1990) and inferior–near neglect reported by Mennemeier et al. (1992). Our findings also represent the first known replication of Kageyama

Table 1. Line bisection performance for the patient and controls. Each participant bisected five lines in each orientation. Mean errors, standard deviations, and confidence intervals are expressed as percentage of total line segment length. Deviations to the right, above, and distal were assigned positive values.

Participant	Horizontal	Vertical	Radial–below eyes	Radial–above eyes
Patient				
	13	−2	8	18
	27	−4	2	10
	12	0	13	26
	24	−9	4	48
	10	−4	12	0
M (*SD*)	17 (8)	−4 (3)	8 (5)	20 (18)
95% confidence interval	10–24*	−7–−1*	4–12*	4–36*
Controls				
M (*SD*)	0 (2)	0 (3)	2 (3)	0 (6)
Range	−3–−4	−7–−6	−4–−7	−13–−10

*Differs significantly from arithmetic midpoint, $p < .05$.

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et al.'s (1994) report of simultaneous three-dimensional neglect following unilateral lesions.

This is also the first known description of all three axes being simultaneously affected by neglect in the context of a unilateral right anterior choroidal lesion. Infarcts in AChA distribution have been previously reported to produce a horizontal (Bogousslavsky et al., 1988; Ferro et al., 1987; Ferro & Kertesz, 1984), vertical (de la Sayette et al., 1995), or radial neglect (Marshall & Halligan, 1995). The combination of left and superior altitudinal neglect in a patient with an AChA infarction was described by de la Sayette and colleagues, but they did not test their patient along the radial axis (de la Sayette et al., 1995). Conversely, Marshall and Halligan (1995) did examine for radial, but not for vertical neglect in a patient with a lesion in the posterior limb of the right internal capsule and thalamus. Their patient also differed from ours in that his line bisections in the radial condition (at desktop level) showed a neglect of far rather than near peripersonal space. However, the line bisections were obtained from Marshall and Halligan's patient much later in the course of recovery, 4 years after the acute event (Marshall & Halligan, 1995). There is preliminary evidence that this long postlesion interval may account for a reversal of line bisection errors (Geldmacher & Kori, 1997) and explain the discrepancy in results.

Geldmacher and Heilman (1994) showed that normal individuals bisect lines above eye level more proximally in the radial plane than lines presented below eye level. This finding suggested the existence of a visual field influence on radial line bisections consistent with Previc's (1990) proposal of a specialization of the upper visual fields for visual attention. In the above-eye-level condition, our patient's bisection errors were distant to true center. Bisections were below true midpoint in the vertical condition. Taken together, these findings indicate that our patient might lack the purported upper visual field bias as a result of his lesion. The normal tendency toward distant bisection in the radial axis would be preserved, even in the absence of the upper visual field bias. Caution is warranted in generalizing the bisection pattern in the radial axis, because not all of Geldmacher and Heilman's (1994) participants showed the pattern of proximal bisections above eye level.

Alternatively, our patient may have had a deficit in directing activity toward near peripersonal space. This was not evident in functional tasks such as eating or reading. Impaired intention toward near space was also not apparent on several random-array letter cancellation forms, which our patient performed without errors. A deficit in intention toward near space can also not explain our bisection results in the vertical plane.

Previc (1990) suggested that the inferior temporo–occipital areas are important for processing upper and far vision. Superior altitudinal neglect is seen after bilateral temporal lesions, which supports this view (Shelton et al., 1990). In macaques, the inferior temporal cortex (area TEO) includes areas with retinotopic organization. There are distinct lower and upper visual field (UVF) regions and the larger area is devoted to the UVF (Boussaoud et al., 1991). Area TEO also projects to cortical areas in the superior temporal sulcus (STS) and intraparietal sulcus among other regions (Distler et al., 1993). STS is well recognized as a homologue of the inferior parietal lobule in humans. A disruption of UVF-biased temporoparietal pathways, analogous to macaque TEO afferents, in or near the posterior limb of the internal capsule might be anticipated in our patient. Such a lesion might deprive parietal polymodal association cortices of some superior visual field inputs, reducing the upper visual field bias. The loss of these inputs could contribute to the inferior misbisection in the vertical plane and distal misbisection above eye level in our patient. This hypothesis would require the continued presence of the normal bias toward distant space.

A concomitant neglect of near space, forcing radial bisections outward, is less parsimonious, but occipitoparietal pathways have been associated with near vision (Mountcastle, 1976). The importance of the parietal lobe in the control of attention in lower and near space has been supported in patients with unilateral and bilateral parietal lesions that resulted in an inferior and near neglect (Guariglia & Antonucci, 1992; Halligan & Marshall, 1991; Mennemeier et al., 1992; Rapcsak et al., 1988). If neglect of near peripersonal space is the cause of the distal radial bisections observed in our patient, a disruption of parietal output pathways is a possible contributor. One likely candidate would be parietothalamic fibers running through the posterior limb of the internal capsule to the nucleus reticularis thalamus (Heilman et al., 1993). The patterns of deficit in our patient would be potentially consistent with a combination of superior vertical and near peripersonal neglect, thus implicating interruption of both temporoparietal (altitudinal) and parietothalamic (radial) processing.

It is important to recognize that these anatomical formulations are highly speculative. Functional brain imaging in patients with infarcts in the distribution of the AChA has demonstrated reduced perfusion in the parietal, prefrontal (Bogousslavsky et al., 1988), and temporal areas (Hublet et al., 1995), as well as in the thalamus (de la Sayette et al., 1995). These are all regions that have been associated with neglect, which complicates any attempt at detailed functional or anatomic localization of the neglect mechanisms in our patient.

In conclusion, therefore, it appears that right anterior choroidal artery distribution lesions are sufficient to produce disordered spatial processing in three dimensions. While different patterns of two-dimensional spatial disruption have been identified following unilateral subcortical lesions, our findings extend the previous results to all three orthogonal axes of space simultaneously. In addition, our observations of bisections in the vertical plane as well as in the radial plane both above and below eye level suggest the loss of an upper visual field bias seen previously in healthy controls. Disruption of fibers carrying ventral temporal, upper visual field-specific, visual association cortex inputs to inferior parietal lobe polymodal association cortex appears to be a plau-

sible contributing factor. It is not clear how generalizable our findings will be. The extent of the spatial distortion, and possibly the mechanism underlying the neglect phenomena, will likely vary by lesion size and location, as well as by the host factors (i.e., individual variability). Future studies might examine the frequency and severity of our observations in larger groups of patients. The impact of subtle spatial processing deficits in the vertical and radial axes on daily function is unknown and also warrants further exploration.

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