Journal of the International Neuropsychological Society (1999), **5**, 75–82.

CASE STUDY

To see better to the left when looking more to the right: Effects of gaze direction and frames of spatial coordinates in unilateral neglect

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(Received February 9, 1998; Revised May 7, 1998; Accepted May 27, 1998)

Abstract

Unilateral spatial neglect entails a failure to detect or respond to stimuli in the space opposite to a brain lesion. However, the contralesional hemispace can be determined by different frames of spatial coordinates, such as eyes-, head-, body-, or environment-centered coordinates. We observed 2 patients with a right hemisphere stroke whose left spatial neglect was modulated by distinct coordinates systems depending on the task. Four tasks were given in different conditions of central gaze and either the eyes or the head rotated 30° to the right or 30° to the left. While the 2 patients had a retinotopic defect in 1 visual field quadrant that remained the same irrespective of gaze direction (upper or lower quadrant in 1 case each), the other quadranopic field defect improved with eyes rotation to the right but not with head rotation, suggesting a head-centered spatiotopic deficit. Performance on line bisection was influenced both by eyes and head rotation, as well as by the position of the lines with respect to the trunk midline, suggesting the involvement of both head-centered and body-centered coordinates. Visual imagery and auditory extinction were not modified by changing the eyes or head position. These findings suggest that distinct spatial coordinates are brought into play depending on the tasks demands. (*JINS*, 1999, *5*, 75–82.)

Keywords: Neglect, Spatial coordinates, Gaze, Hemianopia

INTRODUCTION

Attention governs the ability to perceive, locate, and respond to stimuli in space. Patients with unilateral spatial neglect fail to attend to the side of space contralateral to their brain lesion. Left and right hemispace, however, can be defined with respect to different frames of spatial coordinates (Bradshaw et al., 1987; Grüsser & Landis, 1991). Egocentric coordinates code locations in space relative to the retina, head, or body midline, while allocentric coordinates are derived with reference to the environment or objects themselves. Distinct maps of space must be simultaneously used in the brain (Andersen, 1995; Bradshaw et al., 1987). For instance, visual stimuli are encoded in retinal coordinates but movements of the eyes, head, and body can alter their retinal locations while their spatial locations in the environment remain constant. The transformation of distinct spatial coordinates into another must be therefore computed for accurate perception and action (Andersen, 1995; Grüsser & Landis, 1991).

The question of how different frames of spatial coordinates contribute to and interact in unilateral neglect has yielded varying and often conflicting answers. As the retino-, head-, body-, and environment-centered coordinates are all aligned in the upright standing or seating position, a number of studies attempted to compare the performance of neglect patients under different conditions that uncouple them. Manoeuvres that have been used include rotation of the eyes (Rapcsak et al., 1987), head (Bisiach et al., 1985; Fuji et al., 1996; Karnath et al., 1991), or trunk (Karnath et al., 1991), lateral tilt of the head (Ladavas, 1987), various body position with respect to the stimuli, such as lying prone, supine or to one side (Calvanio et al., 1987; Farah et al., 1990; Mennemeier et al., 1994), or various stimuli position with respect to the body (Bisiach et al., 1985; Farah et al., 1990; Fuji et al., 1996; Rapcsak et al., 1987). These studies provided evidence that unilateral neglect can be influenced by

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https://doi.org/10.1017/S1355617799511107 Published online by Cambridge University Press

retinal (Ladavas, 1987; Rapcsak et al., 1987), head (Fuji et al., 1996; Husain, 1995), trunk (Bisiach et al., 1985; Calvanio et al., 1987; Farah et al., 1990; Karnath et al., 1991), environment (Calvanio et al., 1987; Farah et al., 1990; Ladavas, 1987; Mennemeier et al., 1994), or object-centered (Chatterjee, 1994; Husain, 1995) coordinates just as well. One possible explanation for the discrepancy among these studies would be the differences in the tasks used, if one assumes that distinct spatial maps might be brought into play depending on tasks demands. This would be consistent with the fact that dissociations between tasks or components of neglect are commonly observed within individual patients (McGlinchey-Berroth et al., 1996) and that differences in the cognitive, perceptual or motor demands of a task may modulate attentional orienting (Marshall & Halligan, 1996; Reuter-Lorenz et al., 1990).

We describe 2 patients whose left spatial neglect was differentially influenced across tasks by changing eyes or head position. These findings support task-related involvement of distinct spatial coordinates in unilateral neglect.

PATIENTS

Patient L.O. was a 64-year-old right-handed bank manager who had a mild left hemiparesis with slight decrease of superficial and deep sensation and marked dysmetria of both upper and lower left limbs. On admission the initial confrontational testing of the visual fields suggested a left homonymous hemianopia in addition to a severe left neglect syndrome that concerned both the extrapersonal space and personal hemibody. During the following days, additional testing disclosed substantial modifications of the visual field defect depending on the patient's direction of gaze. His ability to detect brief finger movements or small targets markedly improved in the left *lower* quadrant of both eyes during right gaze (i.e., rightward eyes deviation) compared to left or central gaze, whereas the visual defect in the *upper* quadrant remained uninfluenced by the eyes position. The phenomenon was consistently reproducible during the next 2 weeks until frank unilateral visual neglect changed to extinction on double stimulation in the lower quadrant with persisting left upper quadranopia. This was further investigated as described below. Visual acuity was normal. Left spatial neglect was demonstrated on several tasks such as writing, drawing, reading, description of pictures, line bisection, as well as in two cancellation tasks (16/32 and 47/56 omitted targets on line crossing and letter cancellation, respectively). There was a left auditory and tactile extinction on bilateral stimulation. Brain CT on admission was normal but MRI 4 days poststroke onset revealed two infarction areas in the territory of the right posterior cerebral artery that involved the medial occipitotemporal region, as well as the posterior lateral and pulvinar nuclei of the thalamus (Figure 1).

Patient G.Y. was a 72-year-old woman, formerly a dressmaker, who had a dense left hemiplegia with decreased touch sensation but preserved pain sensation, severe left spatial neglect, and anosognosia. While confrontational testing of the visual fields in central gaze suggested a left homonymous hemianopia with a clear-cut demarcation on the midline, substantial modifications of the field defect were observed depending on the patient's direction of gaze. Detection of brief finger movements markedly improved in the left *upper* quadrant of both eyes during rightward gaze, but only minimally during rightward deviation of the head. The visual defect in the *lower* quadrant was uninfluenced by eyes position. This was consistently reproducible during the next 2 months of follow-up and further investigated as described below. Visual acuity was normal. Left spatial neglect was observed on writing, drawing, reading, picture description, line bisection, and cancellation tasks (21/32 and 43/56 omitted targets on line crossing and letter cancellation, respectively). There was also left auditory and tactile extinction on bilateral stimulation. Brain CT 4 days after onset re-

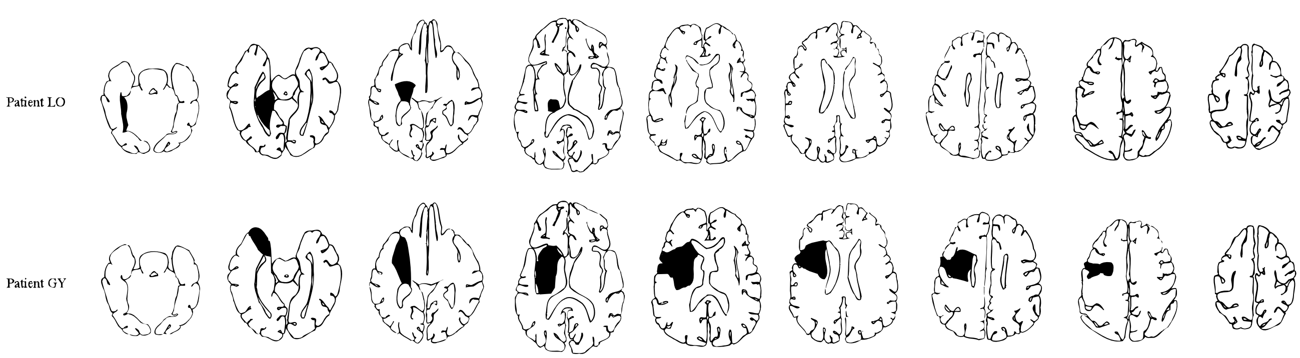

Fig. 1. Reconstruction of the brain lesions in the 2 patients following the methods of Damasio and Damasio (1989). Patient L.O. had two areas of infarction in the territory of the posterior cerebral artery, one involving the medial occipitotemporal and parahippocampal gyri, the other involving the posterior lateral and pulvinar nuclei of the thalamus. Patient G.Y. had an infarct in the territory of the right middle cerebral artery that involved the central, premotor, and opercular regions of the frontal lobe (Brodmann areas 4, 6, 44 and 47) and the anterior parietal lobe (areas 1, 2, 3), as well as the insula and the superior temporal lobe (area 38), extending more deeply into subcortical structures and paraventricular white matter.

vealed an infarction in the territory of the right middle cerebral artery that mainly involved the central, premotor, and opercular regions of the frontal lobe, the anterior parietal lobe, and the adjacent subcortical white matter (Figure 1).

METHODS

All the investigations were performed during the 2nd week post-stroke onset in patient L.O. and the 4th week post-stroke onset in patient G.Y. The same tasks were given to both patients under five conditions that each required a different gaze direction, always in the following order: eyes and head in primary position (*center*); eyes maintained approximately 30° to the left (*eyes-L*) or approximately 30° to the right (*eyes-R*), the head position aligned with the body axis; head rotated approximately 30° to the left (*head-L*) or approximately 30° to the right (*head-R*), the eyes position in alignment with the head axis (see Figure 2A). One examiner continuously controlled the patient's head or eyes position. Four tasks were administered; in the first two G.Y. received fewer trials than L.O. because of greater fatigability and poorer cooperation.

1. Visual fields were tested by a simple perimetry method using a white screen placed approximately 50 cm in front of the patient and a 3 × 3 mm red sphere mounted on a

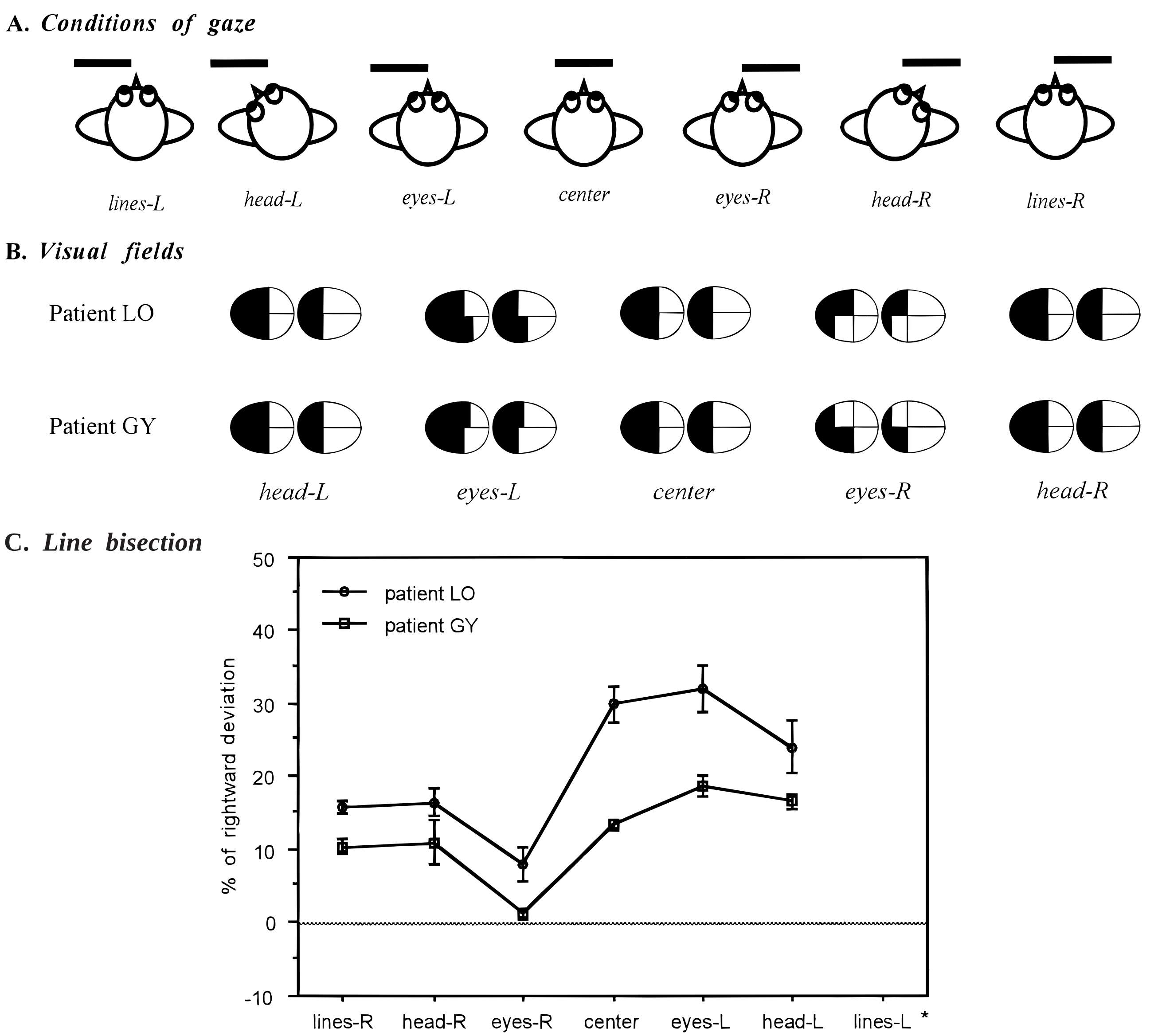

Fig. 2. (A) Schematic representation of the gaze conditions and the stimuli positions used in the different tasks. (B) Schematic plot of the visual field defects as obtained from the perimetry task under each gaze condition in the 2 patients; the defects were very reproducible and overlapped within less than 2° across the different blocks within one session and less than 4° across sessions. (C) Mean percentage of rightward errors in the line bisection made by the 2 patients under each gaze condition. Bars indicate standard errors. The *line-L* condition (*) could not be achieved in either case.

https://doi.org/10.1017/S1355617799511107 Published online by Cambridge University Press

stick as target. The target moved slowly on the screen from the periphery toward the center and locations where it could be detected by the patient were plotted. After a few practice trials, radially moving stimuli were randomly presented in each of the four visual quadrants to each eye separately and then to both eyes simultaneously. Fixation was controlled to be maintained on a cross at the center of the screen. Patient L.O. was given two blocks of 10 trials in each quadrant and patient G.Y. two blocks of five trials (i.e., 20 and 10 trials per quadrant, respectively). The whole procedure was repeated in patient L.O. on a second session 1 day later.

2. Line bisection was assessed using horizontal lines printed on 42 × 29 cm white sheets that were presented in the frontal plane at a distance of approximately 50 cm, with their center aligned with the patient's gaze fixation point. Both patients bisected lines under each of the five gaze directions described above, as well as under two additional conditions where the lines were placed either 30 cm to the left (*lines-L*) or 30 cm to the right (*lines-R*) relative to their body midline while the eyes and head were maintained straight ahead. These two additional conditions were intended to distinguish the effects of moving the patient's eyes and head coordinates from those of moving the stimuli in each side of his hemispace without changing the eyes or head position. Doing so also resulted in having the lines in distinct visual hemifields. In patient L.O., both long (206 mm) and short (144 mm) lines were alternated in two separate blocks of 12 trials in each condition (six for each line length); patient G.Y. was given two blocks of four trials each using only one line length (206 mm). In patient L.O., the whole procedure was repeated on a second session 1 day later. The patients always used their right hand. Line bisection errors were measured as the mean displacement from the true center of the line (in millimeters) for each line length and percentage of deviations were calculated as the proportion of the bisection displacement divided by the line length.

3. Mental imagery was tested by asking the patients to describe the buildings along well-known city places as viewed from different standing points and cities along the banks of a well-known lake as imagined from a map of Switzerland (Test A). Each of these two tasks was considered to include at least three left-sided and three right-sided target items to be reported. To control for repetition effects, the two tasks were alternated and the five gaze conditions were intercalated amid the other tasks. Another task (Test B) involved imagery for buildings and shops along one of the main street in the city as seen from a tramway going in one direction or the other, though this was not tested in all conditions in the 2 patients (each task was performed in a different session).

4. Dichotic listening assessed unilateral auditory extinction using a series of monosyllabic words that were presented in triplets to both sides simultaneously through earphones. Patients had to repeat aloud each of the words. Each series comprised 30 different words delivered to each side. A different series was used in each of the five gaze direction conditions.

RESULTS

1. In both patients, while a complete left hemifield defect with strict demarcation on the midline was apparent during testing in the primary gaze condition, a substantial expansion of the visual field could be documented during rightward deviation of the eyes (Figure 2B). In both cases, the expansion subtended about 25° of visual angle and was restricted to one quadrant, the lower left field in patient L.O. and the upper left field in patient G.Y. Only moderate enlargment of the visual defect encroaching on the right field was found during leftward deviation of the eyes in both cases (about 15° in L.O. and 10° in G.Y.). Rotation of the head had no effect. The left upper field defect of L.O. and the left lower field defect of G.Y. remained unchanged with a marked demarcation on midline irrespective of the direction of eyes or head. These findings were similar for the two eyes examined separately or simultaneously. Furthermore, the plotted defects were very consistent and reproducible in the 2 patients, with their demarcation almost exactly overlapping and showing the same magnitude of change across the different blocks (or sessions in the case of L.O.).

2. Both patients made bisections errors to the right of the actual midpoint in all conditions (Table 1). The percentage of deviation significantly differed across the different conditions (Kruskall–Wallis rank test, $H = 29.5$ and 27.7 for L.O. and G.Y., respectively; $df = 4$; $p < .0001$ in both cases). Patient L.O. performed similarly for short and long lines, and percentage of rightward deviations were pooled across line length for analysis. Pairwise comparisons between the conditions were performed on the percentage of deviation using Wilcoxon's test for matched pairs. Figure 2C shows that left neglect was significantly decreased both during eyes and head rotation to the right in both cases (L.O.: $p = .002$ and .004, respectively; G.Y.: $p = .012$ and .049, respectively; Wilcoxon's test), while there was no significant change in bisection errors with eyes and head deviations to the left (L.O.: $p = .58$ and .16, respectively; G.Y.: $p = .012$ for both comparisons). Placing the lines in the right space with respect to the patient's body midline (*lines-R* condition) also improved left neglect compared to the center condition (L.O.: $p = .002$; G.Y.: $p = .027$). This effect did not differ from that of head rotation to the right (*head-R* condition; L.O.: $p = .53$; G.Y.: $p = .26$), indicating that the critical factor was the spatial location of lines with respect to the body or environment coordinates. Both the effect of a right position of the lines and the effect of a right rotation of the head were however

Table 1. Line bisection performance by patients L.O. and G.Y.

	Line bisection errors			Visual imagery (number of reported items)				Dichotic listening (number of repeated words)	
				Test A		Test B			
Conditions of gaze	Line length	*M* rightward displacement (*SD*)	*M* proportional deviation	Left-side	Right-side	Left-side	Right-side	Left ear	Right ear
Patient L.O.									
I. Centered	144 mm	34 mm (8)	}29%	2/3	2/3	7	6	6/30	24/30
	206 mm	75 mm (10)							
II. Eyes-to-left	144 mm	44 mm (16)	}32%	2/3	3/3	—	—	4/30	25/30
	206 mm	68 mm (24)							
III. Eyes-to-right	144 mm	8 mm (8)	} 8%	2/3	2/3	—	—	4/30	25/30
	206 mm	21 mm (20)							
IV. Head-to-left	144 mm	33 mm (16)	}23%	2/3	2/3	—	—	4/30	24/30
	206 mm	48 mm (29)							
V. Head-to-right	144 mm	21 mm (10)	}17%	2/3	2/3	—	—	5/30	25/30
	206 mm	38 mm (10)							
VI. Lines left to body	144 mm	the patient could not achieve the task							
	206 mm								
VII. Lines right to body	144 mm	25 mm (3)	}16%						
	206 mm	30 mm (6)							
								Monaural listening	
								30/30	30/30
Patient G.Y.									
I. Centered	206 mm	28 mm (3)	}14%	1/3	3/3	2	22	0/30	26/30
II. Eyes-to-left	206 mm	39 mm (6)	}19%	1/3	3/3	—	—	0/30	24/30
III. Eyes-to-right	206 mm	3 mm (3)	} 1%	1/3	3/3	—	—	0/30	22/30
IV. Head-to-left	206 mm	22 mm (4)	}11%	2/3	2/3	1	14	0/30	24/30
V. Head-to-right	206 mm	23 mm (12)	}12%	1/3	3/3	0	12	0/30	24/30
VI. Lines left to body	206 mm	the patient could not achieve the task							
VII. Lines right to body	206 mm	21 mm (4)	}10%						
								Monaural listening	
								23/30	30/30

*Test A refers to the description of a well-known city place or towns on an imagined map; each condition included three critical items on both the left and right side and they were alternated with other tasks. Test B refers the description of a well-known city street as imagined from a tramway going in one or the other direction; each condition was given in different sessions in patient G.Y. See Methods.

significantly less than that of a right rotation of the eyes (*eyes-R* condition; L.O.: p = .028 and .021, respectively; G.Y.: p = .012 for both comparisons). The bisection of lines placed in the left space relative to the body midline with gaze kept straight ahead (*lines-L* condition) proved to be virtually impossible in both patients because the lines then fell in their blind left hemifield.

3. While patient L.O. had no apparent defect in mental imagery, patient G.Y. consistently neglected the left-sided items of visual scenes, but this was not affected by eyes or head deviations (Table 1). In describing the tramway's route along the city main street (on different sessions), for one imagined direction (from Station A to B) G.Y. reported 2 left and 12 right side items in the *center* condition, one left and eight right side items in the *head-L* condition, and no left but six right side items in the *head-R* condition. Yet, for the other imagined direction (from Station B to A) G.Y. neglected the previously reported items but reported the previously neglected ones, that is, respectively, no left and 10 right items (*center*), no left and six right items (*head-L*), and no left and six right items (*head-R*). There was thus no significant difference in the total number of left *versus* right items across these three conditions (Table 1; $\chi^2 = 1.03$; $df = 2$; $p = 0.59$). The task could not be reliably replicated in the *eye-L* and *eye-R* conditions because of poor cooperation in sustaining the position. Patient L.O. showed no imagery defect in a similar task in the *center* condition but was unfortunately not tested in the other conditions.

4. Left auditory extinction during dichotic verbal listening remained similarly severe in both patients irrespective of their eyes or head position.

https://doi.org/10.1017/S1355617799511107 Published online by Cambridge University Press

DISCUSSION

In both patients, dissociating different frames of spatial coordinates by head or eyes turns produced distinct effects on left spatial neglect in two tasks and no effect in two others. A clear dissociation between retinotopic and spatiotopic visual perception was demonstrated across the lower and upper visual field. Lower and upper field defects further dissociated between the 2 patients. The left upper quadranopia of L.O. and the lower quadranopia of G.Y. were not modified by eyes or head position, being consistent with visual loss in retinal coordinates and damage to the ventral geniculostriate pathways in L.O. and the dorsal geniculostriate pathways in G.Y. This is in accordance with L.O.'s inferomedial occipital lesion and G.Y.'s mainly subcortical parietal lesion as demonstrated by MRI and CT, respectively, although damage to the dorsal geniculostriate radiations in the case of G.Y. might be rather suspected than directly apparent on the early available CT images (4 days poststroke). On the other hand, more importantly, the left lower quadranopic defect of L.O. and the left upper quadranopic defect of G.Y. markedly improved with rightward gaze and slightly expanded with leftward gaze, being consistent with hemispatial rather than hemiretinal coordinates, that is, left visual neglect rather than true quadranopia. When the gaze is directed straight ahead, the hemispatial attentional and hemiretinal visual fields are aligned and overlap, whereas lateral gaze permits to dissociate them by bringing most of both retinal fields in the same hemispace. In both patients, however, effects of gaze direction on the visual field defect were only obtained with eye rotation, whereas head rotation with the eyes maintained aligned in the head's midsagittal plane produced no significant change. Therefore, in this condition, hemispatial inattention appeared as primarily tied to head-centered rather than body-centered coordinates. In contrast, line bisection was affected not only by eye direction, but by head rotation and lines position with respect to the body midline as well. While turning the head rightward or placing the lines right to the body midline with the head kept in the central position improved left neglect to the same magnitude, turning the eyes to the right had a further beneficial effect. This implies that spatial allocation of attention during the line bisection task used a distinct frame of reference as opposed to the visual hemifield testing, being determined both by head-centered coordinates and body-centered (or environment-centered) coordinates.

These effects cannot be explained by an activation of hemispheric attentional processes caused by the lateral orientation of gaze as suggested by Kinsbourne's theory (Kinsbourne, 1987). According to the latter, lateralized responses are presumed to boost the level of activation of the contralateral hemisphere, and hence to enhance the attentional orienting bias of that hemisphere to the opposite side of space. However, such an activational mechanism would result in an improvement of left neglect with conditions of gaze turning to the left (i.e., head-L or eyes-L conditions) and not to the right, which is the opposite of our findings. For the same reason, our findings cannot be explained neither by spatial or motor cueing effects due to the position of stimuli or to the use of the right hand for line bisection (Halligan et al., 1991; Robertson & North, 1992), as such cuing effects would also result in opposite changes.

Similar gaze-dependent visual field defects have been reported in only two previous cases. One patient had left spatial neglect and a left hemianopia that abated when his eyes were directed 30° into the right hemispace; no or only minimal change was found with left gaze (Kooistra & Heilman, 1989). Another patient had no sign of spatial neglect but his apparent left hemianopia in primary gaze position nearly resolved when he looked 30–40° to the right (especially in the upper quadrant); again only minimal change was observed with left gaze (Nadeau & Heilman, 1991). In neither cases were effects of head rotation investigated, nor was their performance in line bisection compared with respect to different direction of gaze. It is worth noting that both patients had an infarct in the inferior and medial occipitotemporal region on the right side, with an additional posterolateral thalamic lesion in the first case, like our patient L.O. This contrasts with most neglect patients who have lesions in the posterior or inferior parietal lobe (Vallar & Perani, 1986). Our patient G.Y. had a lesion centered on the frontal lobe and anterior rather than posterior parietal lobe that extended into the subcortical white matter. Thus, as the two previously reported cases, our patients had somewhat unusual lesions. We might therefore hypothesize that integrity of both the primary visual pathways and some posterior parietal areas could be required to produce gaze-dependent defects of the visual fields. In monkeys, the posterior parietal cortex (area 7a) contains neurons that respond both to the retinal location of visual stimuli and to the position of the eyes and can thus compute the locations of objects in hemispatial coordinates (Andersen, 1995; Andersen et al., 1985). A number of such neurons appear to encode locations with respect to head-centered coordinates (Andersen, 1995; Zipser & Andersen, 1988). Other neurons have their receptive field equally affected by eyes and head position, indicating that they encode space in body-centered coordinates (Brotchie et al., 1995). The mechanisms subserving such coordinates transformation in the parietal cortex might underlie gaze-dependent effects in attention-related deficits of visual perception. Alternatively, but less likely in our view, the effects of gaze direction on visual function could be mediated by a parallel visual system related to the superior colliculus and other subcortical extrastriate pathways (Rafal et al., 1990; Zihl & von Cramon, 1979).

Our finding that both body-centered and head-centered spatial coordinates had independent effects in the line bisection task in both patients is similar to the result of a recent study (Fuji et al., 1996). These authors compared bisection errors made by neglect patients under four conditions systematically varying the position of the head and the position of the stimuli with respect to the body midline. They found effects of both head-centered and body-centered coordinates in all cases. Similarly, in a blind tactual exploration task, the performance of neglect patients was influenced both by the position of the trunk midline and the head direction (Bisiach et al., 1985). However, neither of the two studies examined the effects of head and eyes position separately. The role of body-centered and environment-centered coordinates in line bisection is further supported by the finding that left neglect usually improves when the stimuli are positioned right to the body midline, whereas it worsens when they are positioned to the left (Heilman & Valenstein, 1979; Mennemeier et al., 1997; Nichelli et al., 1989), as it occurred indeed in both patients L.O. and G.Y. (but see Riddoch & Humphreys, 1983, for opposite findings). A similar influence of space position on line bisection also occurs in normal subjects (Mennemeier et al., 1997; Milner et al., 1992).

How to explain the differential effects of body-centered spatial coordinates on visual field function and line bisection errors? We believe this is likely related to the different nature of the tasks. Whereas hemifield testing is a purely perceptual task of visual detection, line bisection requires the patient to direct a manual response to the stimuli. In monkeys, the ability to attend to various locations in space has been shown to depend noticeably upon brain areas that are involved in organizing goal-directed movements to them (Rizzolatti & Camarda, 1987; Rizzolatti et al., 1983; Shadlen, 1997; Snyder et al., 1997). Thus, compared to a purely perceptual visual condition, goal-directed action such as line bisection probably involves additional neural systems implicated in spatial coding, either in premotor (Rizzolatti & Camarda, 1987) or posterior parietal (Snyder et al., 1997) cortices. As these systems operate predominantly in body-centered and environment-centered coordinates to perform accurately directed action to external stimuli (Andersen, 1995; Graziano & Gross, 1995), it is conceivable that the influence of such spatial coordinates on unilateral neglect might become apparent only in tasks that require a motor response.

In this respect, it is notable that unilateral neglect on line bisection (Bisiach et al., 1990) or cancellation tasks (Bisiach et al., 1995; Tegnér & Levander, 1991) can be modulated or even reversed in some patients depending on the perceptual or motor demands of the task. Specifically, this led Bisiach et al. (1995) to suggest that space representation might be modulated by response mechanisms and involve independent limb movement-related (“melokinetic”) and eye movement-related (“ophthalmokinetic”) components. Distinct effects of body-centered and head-centered coordinates on spatial neglect might be thus the result of such differences in premotor-intentional mechanisms of directing eyes or manual response towards the external space (Rizzolatti & Camarda, 1987; Shadlen, 1997; Snyder et al., 1997).

That different tasks probably involve distinct spatial maps is further exemplified in our cases by the lack of eyes or head position effects on visual imagery and auditory extinction. In the first imagery task (Test A) which was similarly administered to both patients), we cannot exclude that the small number of target items may have not permitted enough variance to measure changes in performance. However, in the second task (Test B), which involved a higher number of items but could unfortunately not be administered in all conditions in the 2 cases, the severe left visual imagery neglect of patient G.Y. showed no effect of combined head–eyes orientation (patient L.O. had no imagery neglect in the baseline central condition). This stands in contrast to other findings in the literature. Thus, eyes or head rotation has been previously reported to modify hemispatial disturbances in the mental representation of visual scenes in 1 neglect patient (Meador et al., 1987). Likewise, though neither head nor eyes rotation permit to bring one ear in the opposite hemispace, significant effects of gaze direction on auditory lateralization and sounds localization have nonetheless been found in normal individuals (Hartmann, 1983; Lewald & Ehrenstein, 1996) and there is evidence that the auditory map of space is linked to gaze position (Bradshaw et al., 1987).

These observations emphasize that different spatial frames of coordinates may be relevant depending on the task or the behavior. The brain probably maintains several simultaneous maps of space in distinct coordinate systems. Each is capable of making an independent contribution to spatial attention.

ACKNOWLEDGMENTS

We are indebted to Drs. F. Assal and R. Du Pasquier, as well as to Mrs S. Ducommun, for having referred these patients and contributed to the reported investigations.

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