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Position of the Egocentric Reference and Directional Arm Movements in Right-Brain-Damaged Patients

Sylvie Chokron

Laboratoire de Psychologie Expérimentale, CNRS ep 617, Université de Savoie, Chambéry, France; and Fondation Opthalmologique Rothschild, Paris, France

and

Paolo Bartolomeo

INSERM Unit 324, Paris, France; and Neuroscience Department, Hôpital Henri-Mondor, Créteil, France

We asked 12 right-brain-damaged patients (6 with left neglect signs and 6 without left neglect signs) to perform a straight ahead pointing task and a visual detection task with lateralized motor response, in order to investigate the relationship between the position of the egocentric reference and response time and accuracy in producing lateralized arm movements. Results showed that there was no correlation between the position of the egocentric reference and neglect signs, nor between the position of the egocentric reference and the latencies to direct a motor response toward either side of space. These findings were interpreted within the context of egocentric hypotheses of neglect. In particular, it was suggested that attentional or intentional neglect signs cannot be considered as a direct consequence of an ipsilesional deviation of the egocentric reference.

INTRODUCTION

Right temporoparietal lesions often induce a unilateral neglect syndrome which entails a major difficulty in responding to stimulations in the contralesional hemispace (Heilman, Watson, & Valenstein, 1993).

Recently, several authors showed that neglect patients suffer from a devia-

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Address correspondence and reprint requests to Sylvie Chokron, Service de Neurologie, Fondation Opthalmologique Rothschild, 25 rue Manin, 75019 Paris, France. Fax: (0033)-01-48-03-68-59. E-mail: chokron@ext.jussieu.fr.

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tion toward the ipsilesional side of their egocentric frame of reference (Chokron & Imbert, 1995; Heilman, Bowers, & Watson, 1983; Karnath, 1994); this deviation, in turn, would be responsible for the impairment of patients' performance on the left side of space in perceptual, motor, and representational tasks.

This hypothesis draws on Jeannerod and co-workers' neurophysiological studies (Jeannerod & Biguer, 1987; Ventre, Flandrin, & Jeannerod, 1984); these authors proposed that in normal conditions, where the sensory inputs (vestibular, somatosensory, visual) which contribute to the activity of the involved brain areas are distributed symmetrically, the egocentric reference is aligned with body midline and splits personal and extrapersonal space in two equal halves. When a unilateral lesion damages one of the neural structures which process these inputs, the egocentric reference deviates toward one direction, thus producing a directional bias in spatially oriented behavior.

This hypothesis received support from recent findings showing that some experimental stimulations (known to affect the position of the egocentric reference, by the way of their vestibular or proprioceptive inputs) may transiently reduce left neglect signs. In particular, vestibular caloric stimulation (Bisiach, Rusconi, & Vallar, 1991; Cappa, Sterzi, Vallar, & Bisiach, 1987; Rode & Perenin, 1994; Rubens, 1985; Vallar, Bottini, Rusconi, & Sterzi, 1993), optokinetic stimulation (Bisiach, Pizzamiglio, Nico, & Antonucci, 1996; Pizzamiglio, Frasca, Guariglia, Incoccia, & Antonucci, 1990), neck-proprioceptive stimulation (Karnath, 1994; Karnath, Christ, & Hartje, 1993), electrical stimulation (Karnath, 1995; Vallar et al., 1995), and leftward trunk rotation (Chokron & Imbert, 1995; Karnath, Schenkel, & Fischer, 1991) can all compensate for both left neglect signs and egocentric deviation.

Karnath (1997) interpreted these results as, ''Compensating spatial neglect symptomatology by manipulating vestibular, optokinetic and neck-proprioceptive input is interpreted as a central 'correction' of neural coordinate transformation, leading to a reorientation of the distorted or deviated egocentric spatial reference frame'' (p. 505).

However, we recently collected evidence that the position of the egocentric reference is not a valid way of predicting the presence or the absence of left neglect signs (Chokron & Bartolomeo, 1997). Our main finding was that right-brain-damaged patients with left neglect can exhibit a leftward bias in pointing straight ahead but also a rightward deviation or no deviation at all. Similarly, right-brain-damaged patients (RBD) free of left neglect signs did not differ from left neglect patients when pointing straight ahead, in that they might also show a leftward, a rightward, or no significant bias. These results confirmed Perenin's findings (1997), in demonstrating that a deviation of the egocentric reference does not always lead to clinical symptomatology of neglect and, conversely, that neglect signs are not always associated with a deviation of the egocentric reference.

The purpose of the present study was to address more specifically the question of whether a deviation of the egocentric reference influences goal-directed movements in space in RBD patients with or without left neglect signs. Indeed, in Karnath's view (1997), the ipsilesional deviation of the egocentric reference in neglect determines a bias of motor behavior in the same direction and to the same extent as the amplitude of the deviation. The problem with most experimental paradigms used thus far to investigate the motor aspects of neglect is that they include a lateralized visual feedback, hence making it difficult to disentangle motor from perceptual aspects of neglect. Recently, Bartolomeo and co-workers devised a reaction time (RT) paradigm in which this problem was minimized by asking subjects to produce a lateralized motor response to centrally presented visual stimuli (Bartolomeo, D'Erme, Perri, & Gainotti, 1998). By using this paradigm with a series of RBD patients, Bartolomeo and co-workers were able to show that a directional motor disorder is not an obligatory component of left neglect, because it is present only in a minority of patients, whatever the severity of their neglect signs in visuospatial tests. These findings, that neglect and ipsilesional deviation of egocentric reference may dissociate (Chokron & Bartolomeo, 1997), as well as neglect and directional hypokinesia (Bartolomeo et al., 1998), leave open the possibility that a deviation of the egocentric reference determines a spatial bias in the same direction in motor behavior, thus inducing a directional hypokinesia. If this were the case, we should expect a close relationship between the position of the subjective sagittal middle and the time to produce left- or right-directed motor responses.

METHOD

Subjects

Twelve right-brain-damaged patients and 10 age-matched controls free of neurological damage consented to participate in this study. All subjects were right-handed, as determined using the Dellatolas' questionnaire (Dellatolas et al., 1988). All the RBD patients showed a left hemiparesis and were engaged in a motor rehabilitation program in the Rehabilitation Unit of the Saint-Maurice National Hospital. Clinical and demographic data are reported in Table 1.

The presence and the severity of hemispatial neglect were assessed by using a battery of visuospatial tests (Bartolomeo, D'Erme, & Gainotti, 1994), which included tasks of line cancellation, identification of overlapping figures, and line bisection.

Procedure

Pointing straight ahead (PSA). Subjects were seated blindfolded in front of a graduated table, trunk and head aligned at 0°, the sagittal middle corresponding to the objective center of the table. Trunk and head positions were carefully monitored throughout the experiment. The task was to point straight ahead with the right (non-hemiplegic) hand. There were 16 trials, 4 with each of the four starting positions: 30° or 15° left (−30°, −15°) or right (+30°, +15°) of the objective center of the table. Before each trial, the subject's arm was positioned at one of these starting points, from which he or she had to point straight ahead, moving the arm along the table, the index fingertip being always in contact with the table (see Chokron & Imbert, 1995). The order of trials was randomized. There was no time limit and the answer was recorded when the subject estimated that his index was pointing ''straight'' ahead. The pointing error was measured to within half a degree, by determining the distance between the pointing position and the objective center, and carried a minus sign for leftward pointings and a plus sign for rightward pointings.

Control subjects' PSA performance was compared to the objective mid-sagittal plane with a two-tailed *t* test, while brain-damaged subjects' performance was compared with a two-tailed *t* test both to the objective mid-sagittal plane and to control subjects' performance.

Visual reaction times with motor response (''traffic light'' paradigm). Following the procedure employed by Bartolomeo and co-workers (1998), a paper board was placed on the computer keyboard, leaving three windows open on three different positions: a right-side area (keys 7, 8, 9, 4, 5, 6 of the numeric keypad), a middle area (keys i, o, p, k, l, ; of the American keyboard), and a left-side area (keys q, w, e, a, s, d). Right- and left-side areas were at about 13 cm from the middle area. Three circles were presented in a vertical array on the midline of the screen, as a traffic light. After an interval of 2000 ms, one of the circles became gray (target). Upon the appearance of an upper target, subjects had to move their right hand from the home position at the center of the keyboard to whatever key was situated in the right-side area; when a middle target appeared, response keys were in the middle area; when a lower target occurred, subjects had to press a key on the left-side area. After every trial, subjects had to place their hand at the home position again. Response time was measured from target onset to key press. One block of 12 practice trials and 10 blocks of 4 upper, 4 middle, and 4 lower target trials each were presented. The order of trials within a block was randomized. Only correct left- and right-directed responses ranging from 100 to 4500 ms were taken into account in the subsequent analysis. At the end of a test session, an inverted version of the motor task was performed (upper target → left-sided response, lower target → right-sided response). The response times for the two versions of the motor task were pooled, in order to minimize possible effects due to vertical neglect or stimulus–response compatibility.

Data analysis. To measure subjects' spatial bias independent of their overall performance level, laterality scores derived from Bryden and Sprott (1981) were used. The rightward bias was estimated by $\lambda = \ln(x_1/x_2)$. Two λ scores were obtained for each patient:

(1) A λ_{VS} was based on performance on the visuospatial battery. Following the procedure employed by Bartolomeo and co-workers (1994), values for x_1 were computed by adding (a) The number of overlapping figures identified on the right side (max. = 10) and (b) the number of lines canceled on the right half of the page (max. = 30). A correction was needed for patients with severe neglect, who canceled only the lines lying on the extreme right of the sheet. In order not to underestimate their neglect, all subjects who did not cross the midline were attributed a score consisting of the total number of omitted lines (right plus left) (max. = 59). (c) The line bisection task was evaluated subdividing the eight lines in 20-mm segments. The sum of the number of segments to the *left* of each subject's bisections (max. = 42) was used to compute x_1.

Values for x_2 were computed in an analogous fashion, i.e., by adding the number of left-sided identified superimposed figures to the number of left-sided canceled lines and to the number of segments to the right of line bisection. Patients were considered affected by unilateral neglect when their λ_{VS} score exceeded the range defined by 3 SDs about the mean of 30 control subjects's performance, as described by Bartolomeo and co-workers (1994).

(2) A λ_{RT} was calculated from the response times in the traffic light paradigm (with x_1 = mean RT for left-directed responses; x_2 = mean RT for right-directed responses).

RESULTS

PSA

Control subjects. The mean deviation when pointing straight ahead with the right hand was toward the right, but did not significantly differ from the objective sagittal middle [$m = +3.75°$; $t(9) = 1.30$, ns] (see Fig. 1).

The effect of the starting point was not significant [$F(3, 27) = 0.72$; ns], at variance with previous results obtained in younger subjects (Chokron & Imbert, 1995).

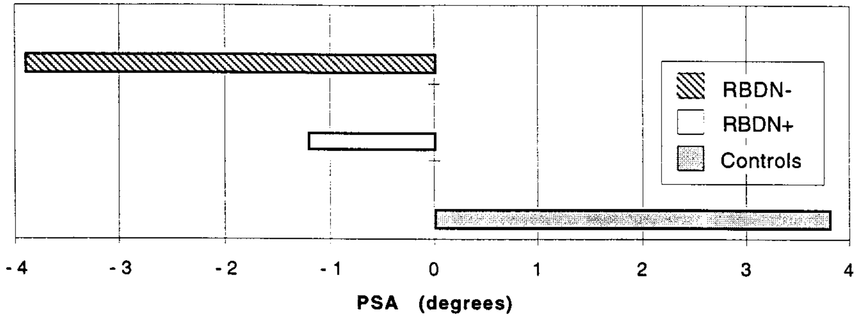

FIG. 1. Mean deviations in pointing straight ahead (in degrees) for control subjects, RBDN+ and RBDN− patients.

RBD patients with left neglect signs ($RBDN^+$). Neglect patients taken as a group, showed a *leftward* bias when pointing straight ahead ($m = -1.2°$); this leftward deviation did not differ from the objective middle [$t(5) = -0.21$; ns] or from the normal controls performance [$t(14) = 0.88$; ns].

The effect of the starting point on the PSA reached significance [$F(3, 15) = 5.54$, $p < .05$]; the more leftward the starting point, the less the subject's pointing deviated to the right; conversely, the more rightward the starting point, the more rightward the deviation, confirming previous results (Chokron & Bartolomeo, 1997; Chokron & Imbert, 1995).

Inspection of individual data (see Table 1) shows that two of the six RBDN+ patients exhibit a significant *rightward* deviation, relative to the objective middle [case 7: $m = +11°$; $t(15) = 3.78$; $p < .05$; case 11: $m = +3.8°$; $t(15) = 4.16$; $p < .05$]; however, it must be noted that only the rightward deviation of case 7 differs significantly from normal controls' performance [$t(9) = 6.37$, $p < .05$].

On the other hand, cases 8 and 9 also made a significant deviation relative to the objective middle and to controls' performance, but in the *leftward* direction [case 8: $m = -24°$; $t(15) = 3.78$; $p < .05$; case 9: $m = -12°$; $t(15) = 10.54$; $p < .05$].

The two remaining neglect patients performed the PSA task with *no significant deviation* relative to either the objective middle or to normal controls' performance [case 10: $m = +1.6°$; $t(15) = 0.75$; ns; case 12: $m = +9.6°$; $t(15) = 1.52$; ns].

RBD patients without left neglect signs ($RBDN^-$). The group of RBD patients without signs of left neglect showed a leftward bias when pointing straight ahead that did not differ from the objective middle [$m = -3.88°$, $t(15) = -0.60$; ns] or from the normal controls' performance [$t(14) = 1.23$; ns], similarly to the RBDN+ group. As was seen for normal controls, the effect of the starting point on the PSA did not reach significance [$F(3, 15) = .46$; ns], as was the case for control subjects.

A separate analysis conducted for each patient revealed that, as for neglect patients, leftward, rightward, or no deviation of the PSA could be observed among nonneglect patients.

Three patients showed a significant leftward deviation relative to both the objective middle and to control performance [case 1: $m = -32°$; $t(15) = 14.9$; $p < .05$; case 3: $m = -6°$; $t(15) = 8.75$; $p < .05$; case 5: $m = -7°$; $t(15) = 6.22$; $p < .05$];

Two patients showed a significant rightward deviation relative to the objective middle [case 4: $m = +12°$; $t(15) = 15.84$; $p < .05$; case 6: $m = +9.7°$; $t(15) = 7.25$; $p < .05$).

Case 2 performed the PSA task with no deviation at all ($m = 0°$, SD 4.68).

Effect of the starting point on PSA performance. Control subjects and RBDN- patients did not show any reliable effect of the starting points on PSA performance. By contrast, the position of the starting points affected

TABLE 1
Demographic and Clinical Data of Right-Brain-Damaged Patients, λ_{vs} scores, pointing straight ahead performance in degrees (PSA), left- and right-directed response times in ms, and integrity of Visual Field

Case No.	Sex, age, years of schooling	Onset of illness (days)	Etiology	Locus of lesion	λ_{vs}	PSA (degrees)	Left-directed responses (ms)	Right-directed responses (ms)	Visual field
1	M, 53, 18	39	Ischemic	IC, BG	0.00	−32	1969	1835	Normal
2	M, 46, 5	113	Hemorrhagic	F	0.00	0	2034	2249	Left extinction
3	M, 53, 5	5	Hemorrhagic	IC, BG	0.01	−6	1468	1358	Left extinction
4	M, 69, 7	151	Ischemic	FPT	0.04	12	2103	1904	Left extinction
5	M, 40, 5	33	Ischemic	FTP, BG	0.09	−7	1585	1513	Normal
6	M, 68, 8	77	Ischemic	FP	0.09	9.7	1759	1162	Left extinction
7	M, 67, 18	37	Ischemic	Th	0.17	11	2762	2650	LSQ
8	M, 43, 8	119	Hemorrhagic	IC, Th	0.22	−24	2093	2039	Normal
9	M, 65, 12	52	Hemorrhagic	FP	0.53	−12	2579	2312	Left extinction
10	M, 46, 6	111	Ischemic	TFP	0.39	1.5	1984	1728	Left extinction
11	M, 43, 11	44	Traumatic	TP	1.57	3.8	2725	2382	LH
12	M, 53, 12	75	Ischemic	BG, IC	2.78	9.6	3233	2924	MA

Note. Lesion site: P, parietal; F, frontal; T, temporal; O, occipital; BG, basal ganglia; Th, thalamus; IC, internal capsule. Visual field: LH, left hemianopia, LSQ, left superior quadranopia; MA, magnetic attraction (systematic rightward deviation of the eyes on double visual stimulation).

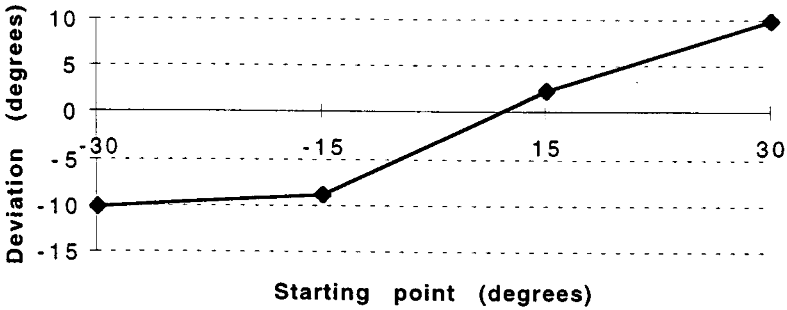

FIG. 2. Effect of the starting point on pointing straight ahead in degrees (PSA) in RBDN+ patients.

RBDN+ patients' performance [$F(3, 15) = 5.53$, $p < .01$]; the further the starting point to the left, the greater the leftward deviation and vice versa for the starting points on the right side (Fig. 2). This finding confirmed previous results (Chokron & Bartolomeo, 1997; Chokron & Imbert, 1995). A linear relationship emerged between the starting position and the final pointing position ($r = .98$, $p < .05$).

Correlation between left neglect signs and PSA. The correlation between left neglect signs (λ_{VS} score) and the position of the egocentric reference (PSA) did not reach significance ($r = .22$, ns), thus confirming our previous results (Chokron & Bartolomeo, 1997).

Traffic Light Paradigm

Figure 3 presents the performance (accuracy and RTs) of control subjects, RBDN+ patients and RBDN− patients on the RT task with lateralized motor response.

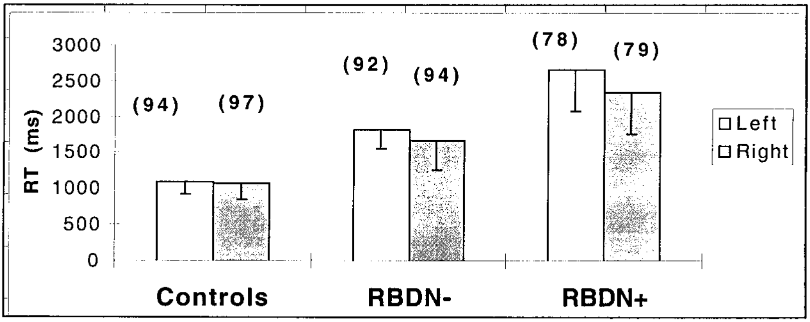

FIG. 3. Mean RTs and percentage of accuracy (in parentheses) for control subjects and RBDN+ and RBDN− patients.

A repeated measures analysis of variance was performed on the mean RTs with group (neglect, nonneglect, control) as between factor and response side (right, left) as within factor. The analysis revealed a significant difference between groups [$F(2, 19) = 36.61$; $p < .0001$]. Post-hoc pairwise comparisons were carried out using Fisher's protected least significant difference. The two groups of RBD patients were slower than the control group on both sides of space (all effects, $p < .05$). The difference between latencies to produce left- or right-directed responses did not reach significance for normal controls [mean difference (MD) = 25 ms, ns] or for RBD patients with neglect signs (MD = 223 ms, ns) or without neglect signs (MD = 149 ms, ns).

Relationship between Pointing Straight Ahead and Performance on the Traffic Light Paradigm

The relationship between the position of the egocentric reference and the lateralized motor responses in the RT task was studied by transforming the differences between left- and right-directed responses in λ scores, which are laterality indexes independent of the overall performance level (see Method).

The correlation between PSA and reaction times did not reach significance for RBDN+ patients ($r = .35$; ns), nor for RBDN− patients ($r = .34$; ns), suggesting that the deviation of the egocentric reference does not induce a directional motor bias in responding to central visual targets.

To test the possibility that only patients with a significant ER deviation demonstrate a corresponding lateralized motor bias, we divided our patient group into patients with significant ER shift (rightward: patients 4, 6, 7, 11; or leftward: patients 1, 3, 5, 8, 9) and patients without ER deviation (patients 2, 10, 12). Neither the presence, nor the side of ER deviation appeared to significantly induce a spatial bias in the traffic light paradigm [$F(2, 9) = 2.36$, ns].

Correlation between Left Neglect Signs and Performance on the Traffic Light Paradigm

The correlation between neglect signs (λ_{VS}) and laterality scores (λ_{RT}) on the RT task did not reach significance ($r = .08$; ns), showing that left neglect signs on visuospatial tasks and directional motor bias in manually responding to visual targets do not necessarily coexist.

Effect of Extensive Parietal Lobe Damage on Performance in PSA and Traffic Light Paradigms

Since recent evidence suggests that a rightward ER shift may emerge only after extensive parietal lesions (Hasselbach & Butter, 1997), we divided our RBD patients into two subgroups, according to the presence or the absence of an extensive parietal lesion. The parietal group (which included patients 4, 5, 6, 10, and 11) indeed showed a rightward deviation on the PSA task ($m = +5.77°$), which proved not to be statistically different from the objective sagittal middle [$t(4) = 0.86$, ns]. Conversely, the remaining patients (who presented a substantial sparing of the parietal lobe, $n = 7$) exhibited a significant leftward deviation [$m = -8.75°$, $t(6) = -2.99$, $p < .05$].

Similarly, an ANOVA performed on the laterality scores derived from RT on the traffic light paradigm for the three groups of subjects (parietal, nonparietal, controls) revealed an effect of extensive parietal lesion on performance in this task [$F(2, 19) = 4.79$; $p < .05$], with parietal patients showing more rightward bias ($m = 0.18$) than nonparietal patients ($m = 0.04$) or controls ($m = 0.03$).

Correlations between the position of the ER and the laterality scores derived from RT on the traffic light paradigm were computed separately for each group of subjects (parietal, nonparietal); again, no correlation reached significance (parietal group, $n = 5$, $r = .51$, ns; nonparietal group, $n = 7$; $r = -0.31$, ns).

DISCUSSION

The present experiments were designed to test the hypothesis of an altered central representation of egocentric space in neglect patients leading to ''(a) an altered perception of body orientation, i.e., to a disparity of the subjective and objective body orientation with a displacement of the subjectively perceived position to the ipsilesional side and (b) to a bias in space exploration in the same direction'' (Karnath, 1997, p. 505). If this were the case, we should have, respectively, expected (a) a systematic ipsilesional deviation of the egocentric reference, with a significant correlation between the presence of left neglect signs and the ipsilesional bias in pointing straight ahead, and (b) a significant correlation between the position of the egocentric reference and the lateralized motor response times to central visual targets.

Replicating and extending our previous results (Chokron & Bartolomeo, 1997), we found no correlation either between the egocentric reference position and left neglect signs or between the egocentric reference position and a directional bias in lateralized motor responses, thus challenging Karnath's hypothesis.

Egocentric Reference and Neglect Signs

In our previous study (Chokron & Bartolomeo, 1997), we found that individual RBD patients with left neglect signs may exhibit a significant leftward, rightward, or no deviation at all when pointing straight ahead, irrespective of the presence or the absence of left neglect signs. Here we extend those observations on a group of 12 RBD patients (6 showing signs of left neglect, 6 without neglect). Also in the present study the position of the egocentric reference and the presence of left neglect signs could not be predicted from each other. This finding apparently rules out any hypothesis which posits an ipsilesional deviation of the reference as the main cause of unilateral spatial neglect.

In the present study, only neglect patients showed a clear effect of the starting point on the position of their subjective sagittal middle. In accordance with previous results (Chokron & Bartolomeo, 1997; Chokron & Imbert, 1995), we found that the more leftward the starting point, the more leftward the deviation and vice versa for right-sided starting positions. This symmetrical prepointing phenomenon might tentatively be explained either as a nondirectional hypometria (i.e., reduced movement amplitude) in neglect patients (see Heilman et al., 1993; Mattingley, Bradshaw, & Phillips, 1992) or as a representational/attentional spatial bias. It is perhaps of interest that our findings seem to mimic earlier results obtained with visual line bisection in left neglect patients (Chokron, Perenin, & Imbert, 1993; Halligan, Manning, & Marshall, 1991; Reuter-Lorenz & Posner, 1990), showing that right-to-left scanning induces a rightward bias (left neglect), while left-to-right scanning leads to the reverse pattern. Because Chokron and co-workers (1993) and Reuter-Lorenz and Posner (1990) observed a similar bias when using a perceptual judgment without any directional motor component, it might be speculated that a representational/attentional deficit contributed more than a motor bias to the prepointing phenomenon that we observed.

Consistent with previous observations (Hasselbach & Butter, 1997), we found an effect of intrahemispheric lesion location on the ER position. Patients with parietal lesion pointed predominantly rightward, although their deviation did not significantly differ from the objective middle. A new and unexpected finding was that patients with substantial sparing of the parietal lobe made a massive leftward deviation relative to the objective midline. While these findings do suggest a specific role of right parietal lobe lesions in determining an ipsilesional ER shift, more data are needed to explain why a reversed ER shift is shown by RBD patients without extensive parietal damage. One might speculate that the leftward ER deviation in these patients may reflect an attempt to compensate for some form of ipsilesional spatial bias.

Egocentric Reference and Directional Motor Bias

The main purpose of the present paper was to test the relationship between a deviation of the egocentric reference and a directional motor response. According to Karnath (1997), and to Jeannerod and Biguer (1987), one should expect that the more the egocentric reference is deviated toward one side, the more the latency to direct a motor response to the other side is increased. However, our results clearly show that there is no significant correlation between the position of the ER and the time to produce left- or right-directed manual responses. In fact, no significant directional bias was found with the traffic light paradigm in our group of RBD patients, either in the six patients with neglect or in the six patients without neglect, thus confirming that directional hypokinesia is not necessarily present in left visuospatial neglect (Bartolomeo et al., 1998; Harvey, Milner, & Roberts, 1995; Ishiai, Sugushita, Watabiki, Nakayama, Kotera, & Gono, 1994a, Ishiai, Watabiki, Lee, Kanouchi & Odajima, 1994b; Mijovic', 1991). In fact, a directional motor bias might be more directly associated with the presence of right parietal damage than with left neglect signs (Bartolomeo et al., 1998). Similar considerations may apply to the presence a rightward ER shift.

However, we found no significant correlation between the ER position and performance on the traffic light paradigm even when patients were divided as a function of the presence and side of ER shift or as a function of the presence or the absence of extensive parietal damage, thus suggesting that there is no direct relationship between the underlying impairments.

Further research is needed to confirm these findings in a larger series of patients; nevertheless, the absence of a close relationship between the results of PSA and RT tasks in our patients, taken together with the fact that some neglect patients showed a leftward deviation or no deviation at all when pointing straight ahead, has two major implications.

First, our results are not compatible with the hypothesis of an ipsilesional deviation of the egocentric reference *responsible* for the perceptuomotor behavior of left neglect patients (Karnath, 1997).

Second, if the egocentric reference frame is not disturbed with a systematic ipsilesional error in left neglect patients, then the interpretation of the compensatory effects on neglect of the various experimental maneuvers reviewed in the Introduction has to be revised. As a matter of fact, these effects have been attributed to a restoration of a correct position of the egocentric reference (superimposed to the objective mid-sagittal plane) permitted by the above-mentioned stimulations, thus leading to a transient remission of neglect signs. A more general explanation of these effects should also take into account the fact that these stimulations are able to reduce nonneglect signs, such as hemianopia (Kerkoff, 1993) or anosognosia (Cappa, Sterzi, Vallar, & Bisiach, 1987; Rode & Perenin, 1994), and the impossibility of creating neglect signs by deviating experimentally this reference with these stimulations in normal subjects (Chokron, 1995).

In conclusion, our results confirm that sensory or motor deficits may be associated with an imbalance between the bilateral neural processing building the egocentric frame of reference (Jeannerod & Biguer, 1987; Ventre et al., 1984), leading to a deviation of the reference (Chokron & Bartolomeo, 1997; Hörnstein, 1979; Perenin, 1997), and point out the specific effect of the presence of a parietal lesion on this phenomenon. However, this deviation is not consistently directed toward the ipsilesional side, nor does it always determine attentional or intentional neglect signs.

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