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Note

Patterns of dissociation between left hemineglect and deviation of the egocentric reference

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Abstract—Sixteen control subjects and six right brain-damaged patients with left hemiparesis (three showing signs of left unilateral neglect, three with no signs of neglect) performed a straight-ahead pointing task with their right hand while blindfolded. The aim was to test the hypothesis that the egocentric reference shows significant ipsilesional deviation in left neglect patients. We found no correlation between the position of the egocentric reference and the presence of neglect signs. Neglect patients, like non-neglect patients, showed leftward, rightward or no significant deviation when pointing straight ahead. Results are discussed with reference to egocentric hypotheses of neglect and experimental remission of neglect. © 1997 Elsevier Science Ltd

Key Words: spatial bias; hemiplegia; straight ahead.

Introduction

Egocentric body coordinates such as the sagittal midline have been proposed to act as a reference for ballistic movements in extracorporeal space [20]. Symmetrical functioning of the multiple neural structures processing sensory information would account for the normal sagittal position of the egocentric reference [20, 40]. According to Jeannerod and co-workers [20, 40], a unilateral brain lesion may produce an imbalance between the bilateral neural processes building the representation of space with reference to the body midline, and in this way a deviation of the egocentric reference. Following this line of reasoning, some authors [22, 24, 35] have argued that a deviation of this egocentric reference system towards the side of the brain lesion occurs in spatial hemineglect. In turn, this ipsilesional deviation would prevent neglect patients from exploring the opposite side of space and from responding to stimuli that occur on that side [22, 24].

Left neglect patients who show a rightward deviation of their egocentric frame of reference have indeed been described. Heilman *et al.* [17] first observed an ipsilesional deviation of straight ahead pointing in neglect patients. They interpreted this deviation as "hemispatial" hypokinesia, because the straight ahead pointing task had no perceptual component. The observation of an ipsilesional deviation of the visual or sagittal straight ahead in left neglect patients has been replicated in several recent studies, and interpreted as a deviation of the egocentric reference that would be responsible for neglect signs [10, 22].

This hypothesis was apparently supported by the possibility of transiently reducing left neglect signs in some experimental stimulations. Vestibular caloric stimulation [5, 8, 16, 31, 32, 36, 39], neck-proprioceptive vibration [22, 25], optokinetic stimulation [23, 30, 35, 37], electrical stimulation [38], and leftward trunk rotation [10, 26] can all compensate for ipsilesional deviation. Karnath [23] interpreted the effect of these manoeuvres as a central "correction" of the defective spatial frame. However, an alternative explanation is that left sensory stimulation, especially when accompanied by leftward eye movements, may induce a leftward orienting of attention, thus reducing rightward spatial bias in neglect [13]. If so, stimulations could temporarily compensate for neglect signs, leaving the underlying disorder unchanged [4]. In this view, the deviation of the egocentric reference can be considered as a consequence of rightward attentional bias in neglect, and not as its cause.

The two above-mentioned hypotheses on the functional significance of ipsilesional deviation in neglect patients generate opposite predictions concerning the relationship between deviation and neglect signs: If the ipsilesional deviation is the crucial mechanism leading to neglect, it should co-exist with neglect signs in all instances. If, on the contrary, the deviation is a consequence of neglect, it might dissociate from other neglect signs, just as different neglect signs can dissociate from each other (see, e.g., Ref. [27]). In this case, the observed dissociation would clearly undermine the view of neglect signs as a direct consequence of an egocentric deviation (see, e.g., Ref. [34]).

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We present evidence that ipsilesional deviation is not an obligatory component of left neglect, and that a significant deviation of the egocentric reference can be present in brain-damaged patients apparently exempt of neglect.

Method

Subjects

Control subjects. Eight normal dextrals (four men aged between 23.7 and 35.1 years, mean: 30.4 years, four women aged between 22.6 and 36.2 years, mean: 31.5 years). Handedness was determined using the Dellatolas' questionnaire [12].

Patients. Six right brain-damaged (RBD) patients with left hemiparesis participated in the study. All 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.

Spatial hemineglect was evaluated using a battery of visuo-spatial tests, which included an overlapping figures test [14], a line cancellation task [1], a line bisection task [11], a letter cancellation task [28], the copy of a landscape drawing composed of five horizontally arranged items [15]. The first three tests were used to obtain a quantitative measure of spatial bias, following the method established by Bartolomeo *et al.* [3]. A laterality score was obtained with the following formula:

$$\lambda = \ln (X_R/X_L)$$

Positive λ scores indicate a rightward spatial bias (thus providing a quantitative estimate of left visuospatial neglect), while negative values indicate a leftward spatial bias.

Values of X_R were computed by adding the following:

1. The number of items identified on the right side of the overlapping figures test (max = 10).
2. The number of lines crossed on the right half of the page of the line cancellation test (max = 30).
3. The sum of the number of segments to the left of each subject's bisections (max = 42) in the line bisection task, in which the eight lines were divided into 20 mm segments.

Values of X_L were computed in analogous fashion, i.e. by adding the items of the left-sided identified superimposed figure to the number of left-sided cancelled lines and to the number of segments to the right of line bisection.

Procedure

Pointing straight ahead (PSA)

The subject was seated blindfolded in front of a graduated table, trunk and head aligned at 0°, the sagittal middle corresponding to the objective centre 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, four with each of the four starting positions: 30° or 15° left (−30°, −15°) or right (+30°, +15°) of the objective centre 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 Ref. [10]). 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 centre, and carried a minus sign for leftwards pointings and a plus sign for rightwards pointings.

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

Results

Control subjects

The mean deviation when pointing straight ahead with the right hand was toward the right and differed significantly from the objective sagittal middle (mean = +1.51°, S.D. = 0.48, $t_{15} = 12.58$, $P < 0.05$; see Table 2), thus confirming previous results [10] (Fig. 1).

Regarding the effect of the starting point, 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 (see Fig. 3), again confirming previous results [10]. The difference between starting at 15° to the left and 30° to the right was statistically significant ($t_3 = 4.39$, $P < 0.05$), as was the difference between starting 15° and 30° to the right ($t_3 = 3.45$, $P < 0.05$).

Right-brain-damaged patients

Brain-damaged patients were classified as showing signs of left neglect when their λ score exceeded the cut-off based upon control subjects' performance in visuo-spatial tests (λ score cut-off = +0.10; for more details see Ref. [3]). Following this procedure, patients no. 1, no. 2 and no. 3 were judged as presenting left neglect signs, while patients no. 4, no. 5 and no. 6 performed similarly to controls in the visuo-spatial battery. Table 2 summarizes the results for the RBD patients.

Table 1. Demographic and clinical data of right-brain-damaged patients

Patient	Sex, age, years of schooling	Handedness	Onset of illness (days)	Etiology	Locus of lesion
1	F, 53, 7	Right	76	Ischemic	Frontal-parietal
2	M, 65, 12	Right	52	Hemorrhagic	Frontal-parietal
3	M, 77, 12	Right	30	Ischemic	Frontal-parietal
4	M, 70, 8	Right	> 1 588	Neoplastic*	Frontal-parietal
5	M, 53, 18	Right	39	Ischemic	Internal capsule, basal ganglia
6	F, 68, 10	Right	72	Ischemic	Subcortical white matter, old left occipital infarctus

*Glial tumour of mixed type (oligodendroglioma-astrocytoma) surgically removed in March 1991.

Table 2. Control subjects and brain-damaged patients: λ score, pointing straight ahead (PSA) in degrees, standard deviation, two-tailed t-test compared to the objective middle and to the controls' performance

Subject	λ score (cut-off=0.10)	PSA (in d°)	S.D.	t/0 (d.f.=15)	t/control subjects (d.f.=15)
controls	–	+1.51	0.48	12.58*	–
case 1	+0.38†	3.80	2.83	2.89*	3.32*
case 2	+0.53†	−11.93	4.32	4.49*	9.56*
case 3	+0.15†	+5.22	11.62	1.79	1.26
case 4	−0.03	−0.38	12.43	0.12	0.60
case 5	0.0	−31.93	8.28	15.42*	14.45*
case 6	0.04	+30.15	13.30	9.06*	8.60*

(−, leftward deviation; +, rightward deviation).
*indicate a significant two-tailed t-test at $P=0.05$.
†Left neglect patients.

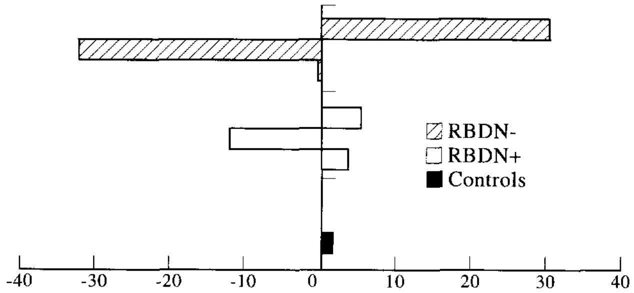

Fig. 1. Mean pointing straight ahead deviation (in degrees) of control subjects, RBDN$^+$ patients and RBDN$^-$ patients.

RBD patients with left neglect signs (RBDN$^+$)

Patient no. 1 had no visual field defect on confrontation test. She showed left visual extinctions on double simultaneous stimulations. She obtained a λ score indicative of left neglect (+0.38). On the letter cancellation test, she cancelled 23/30 As on the right side of the sheet and 1/30 on the left side. She copied all the items of the drawing, but beginning from the right half of the sheet, without filling the leftmost quarter of it.

When pointing straight ahead, she significantly deviated to the right (mean = +3.8°, $t_{15}=4.49$, $P<0.05$) (Fig. 1). This deviation differed significantly from the control subjects' performance ($t_{15}=3.18$; $P<0.05$). The starting point influenced pointing performance: the more rightward the starting point, the more rightward the subjective middle (see Fig. 2). The difference between starting 30° to the left versus 30° to the right was statistically significant ($t_3=3.73$, $P<0.05$).

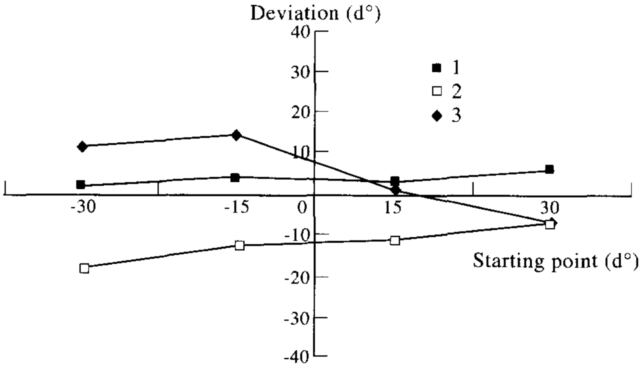

Fig. 2. Effect of the starting point on pointing straight ahead in RBDN$^+$ patients.

Patient no. 2 had no visual field defect on confrontation test. He extinguished left visual stimuli on double simultaneous stimulations. Visuospatial testing disclosed severe left neglect (λ score = +0.53; 9/30 As cancelled in the rightmost part of the sheet to its centre). Nevertheless, he pointed straight ahead with a massive leftward deviation (mean = −11.9°, $t_{15}=11.01$; $P<0.05$), that differed significantly from control subjects' performance, ($t_{15}=9.56$; $P<0.05$). Pointing performance was again dependent upon the starting point: the more rightward the starting point, the less leftward the subjective middle (see Fig. 2). The difference between starting 30° to the left versus 30° to the right was statistically significant ($t_3=6.35$, $P<0.05$), as was the difference between starting 30° to the left versus 15° to the right ($t_3=3.82$, $P<0.05$).

Patient no. 3 had no visual field defect on confrontation test. He showed left extinctions on double visual stimulation, and left neglect signs on the visuospatial battery (λ = +0.15; 24/30 As cancelled on the right side, 12/30 on the left side; all the items of the drawing were copied, but beginning from the centre and proceeding toward the right side). His pointing straight ahead did not differ significantly from the objective straight ahead (mean = +5.22°, $t_{15}=1.79$; n.s.), or from the control subjects' performance ($t_{15}=1.26$; n.s.). The starting point also had an effect on the position of the subjective straight ahead, but in the opposite direction to the other subjects; starting from the right induced a more leftward deviation than starting from the left. Starting 15° to the left differed significantly from starting 15° to the right ($t_3=3.62$ $P<0.05$) (see Fig. 2).

RBD patients exempt of neglect signs (RBDN$^-$)

Patient no. 4 had no visual field defect or visual extinctions on confrontation test. He showed no neglect signs on the visuospatial battery (λ = −0.03), and pointed straight ahead with no significant deviation relative to the objective midsagittal point (mean = −0.38°, $t_{15}=0.12$; $P>0.05$), or to the control subjects' performance, ($t_{15}=0.60$; $P<0.05$). Even if the most rightward deviation occurred with the most rightward starting position (mean = +11°), there was no significant difference between the different starting points (see Fig. 3).

Patient no. 5 made no omissions on either single or double visual stimulation. He showed no neglect signs in visuospatial tasks ($\lambda=0.00$; a single left omission in the letter cancellation test, correct copy of the drawing). However, his pointing straight ahead deviated significantly to the left (mean = −31.93°, $t_{15}=15.42$; $P<0.05$) and differed significantly from

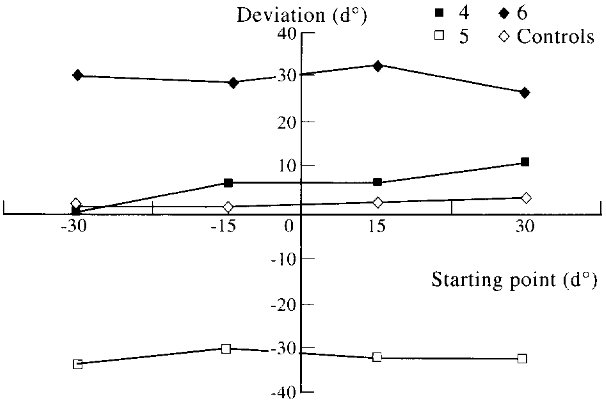

Fig. 3. Effect of the starting point on pointing straight ahead in control subjects and RBDN$^-$ patients.

the control subjects' performance, ($t_{15}=8.28$; $P<0.05$). There was no effect of the starting point on the deviation (Fig. 3).

Patient no. 6 showed sequelae of right hemianopia due to an old left occipital infarctus. She perceived right-sided stimuli at a distance of about 10° from the fovea, and under these conditions showed no visual extinctions on double simultaneous stimulations. She had no neglect signs in visuospatial tests ($\lambda=+0.04$; no omissions on the letter cancellation test and on the copy of the drawing). When pointing straight ahead, she exhibited a significant rightward deviation (mean $=+30.15°$, $t_{15}=15.42$; $P<0.05$), that also differed significantly from the control subjects' performance ($t_{15}=13.30$; $P<0.05$). Again, the starting point had no influence on the deviation (Fig. 3).

In summary, the control subjects deviated significantly to the right when pointing straight ahead with their right hand, in agreement with previous results [10]. Among the three RBD patients who showed left neglect signs (patients 1–3), one significantly deviated to the right (patient no. 1), one to the left (patient no. 2), and one not at all (patient no. 3). Among the three RBD patients without signs of neglect (patients 4–6), one significantly deviated to the right (patient no. 6), one to the left (patient no. 5), and one not at all (patient no. 4). On the whole, λ scores of RBD patients did not correlate with the position of the subjective straight ahead ($r=-0.08$, n.s.). Only the control subjects and RBDN$^+$ patients exhibited significant differences between the different starting points. Except for patient no. 3 (who showed no significant bias), the effect of the starting point on the subjective straight ahead was always in the same direction: the further the starting point to the left, the greater the leftward deviation, and vice versa for rightward starting points. There was no significant influence of the different starting points among RBDN$^-$ patients.

Discussion

Control subjects' performance confirmed previous results showing that the position of the subjective straight ahead deviates significantly towards the side of the hand used [10]. Our main finding is 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. In the same way, right brain-damaged patients exempt of neglect signs did not differ from neglect patients when pointing straight ahead, insofar they also had leftward, rightward or no significant bias. Interestingly, no correlation was found between the presence or absence of a bias in pointing straight ahead and the λ score; nor between the side of the bias and the λ score. In the same way, the presence of a right parietal lesion did not necessarily induce an ipsilesional deviation of the subjective straight ahead (see case nos 1 and 2).

As reviewed in the Introduction, temporary remission of left neglect signs can occur after caloric vestibular, optokinetic, or electrical stimulation, neck muscle vibration, and trunk rotation. As the above stimulations are known to affect the position of the egocentric reference, some authors defended the idea that neglect behaviour might result from a disturbance of the egocentric frame of reference (in the form of an ipsilesional deviation of the egocentric axis). From this point of view, a remission of neglect signs during the different experimental stimulations would be obtained by re-establishing a normal position of the egocentric reference.

However, Bisiach *et al.* [4] proposed a different interpretation of the effects of stimulations, that "may indeed depend on a temporary suppression or mitigation of a symptom, leaving the underlying (distorded) spatial representation unchanged (p. 852)". On the other hand, Gainotti [13] suggested that the improvement in neglect symptoms observed after vestibular or optokinetic stimulation was due to an increase in selective attention to the contralesional parts of body and space. Thus, it is not necessary to postulate the existence in neglect of a systematic and consistent ipsilesional deviation of the egocentric frame of reference that is corrected by stimulation.

As previous studies have shown, the position of the egocentric reference may be displaced with no sign of spatial disorganization. This has been observed in patients with acute unilateral peripheral vestibular disorders [19], patients with optic ataxia [29] and in normal subjects following prolonged exposure to prismatic displacement of the visual scene [18]. However, no neglect signs were observed in any of these stimulations.

The finding that two of our RBDN$^-$ patients with hemiparesis show a consistent deviation of their straight-ahead pointing may suggest that not only a primary sensory deficit, as in the above-cited studies, but also a primary motor deficit might affect the position of the egocentric reference. Asymmetries in space processing have been described in normal subjects [6, 7, 9, 33] but, as Karnath [24] and Perenin [29] pointed out, while stimulations improve neglect of controlateral stimuli in brain-damaged patients, stimulation of normal subjects or egocentric deviation in brain-damaged patients does not necessarily induce neglect signs.

In conclusion, the present results and several other experimental findings suggest that an interpretation of neglect based only on deviation of the egocentric reference is premature, as perhaps is any hypothesis aiming to reduce the complexity of neglect phenomena to a single causal mechanism or to a single deficit. There is indeed evidence that neglect behaviour may result from an interaction among several deficits [14, 21] and compensatory mechanisms [2]. Future research should aim at defining the relationship between these components and egocentric deviation in neglect.

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