Mirror images and unilateral spatial neglect

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Abstract

Responding correctly to a mirror image requires the creation of a rather peculiar form of dual representation. Mirror agnosia and mirror ataxia, i.e. a deficit in reaching an object reflected in a mirror, have been reported to be associated with parietal lobe lesions. This prospective study was conducted to investigate the capacity of subjects with neglect to identify the mirror image nature of visual information. Four consecutive brain-damaged patients with neglect, selected on the basis of specific criteria, and four control subjects performed grasping and object displacement tests under two response conditions (normal mirror and inverted mirror). Video recordings of the tests were analyzed to assess performance using the following criteria: (i) direction of the arm movement during the initial phase of movement, (ii) number of corrections of the hand position before grasping. The control subjects successfully grasped the objects in both experimental conditions. The patients (1) neglected the contralesional space, grasping objects correctly in the ipsilesional space (normal mirror condition) and (2) neglected the ipsilesional space, grasping correctly objects in the contralesional space (inverted mirror). Controls used real object-centered correction clues to modify the position and direction of their hand movement. The patients only produced horizontal displacements of the upper limb in the ‘healthy’ and neglected space. These results suggest that patients with neglect do not use the same clues and do not modify their procedures as they cannot recalibrate their spatial representations. These differences concerned non-mirror-image clues and directional and positional as well as attentional vectors. Theoretical and rehabilitative implications are discussed. © 2001 Elsevier Science Ltd. All rights reserved.

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1. Introduction

Mirrors are used in everyday life to explore and control space not directly accessible to vision. Recognition of the mirror-image nature of visual information requires specific processing procedures and construction of adapted mental representations. For these representations to be constructed, the collected information must undergo specific perceptivo-attentional processing (rotation, inversion, depth,…). Such procedures are probably simple for recognition and control of one’s face or body, especially since the mirror plays a determining role in the construction of body-image and self-image during childhood. To control extrapersonal space these procedures become complex, probably requiring complementary, ‘non-mirror-image’ information. Different perturbations of mirror-image information processing have been reported in patients with parietal lesions. Ramachandran et al. [17] reported a new neurological sign called ‘mirror agnosia’ following right hemisphere stroke with left visual field neglect. Binkofski et al. [2] described two types of behavior in using mirrors in 13 patients with parietal lobe lesions (6 left, 6 right and 1 bilateral). Only one of the patients suffered from neglect. The patients with mirror agnosia searched for the virtual object in the mirror and were unable to modify their behavior even after presentation of the position of the object in real space. The mirror ataxia patients tended to start by searching for the virtual image in the mirror but very rapidly learned to guide their arm to the real object. Mirror agnosia probably resulted from the lack of recognition of the
mirror-image nature of the reflected visual input. Patients with incomplete procedures for processing mirror-image information exhibited directional anomalies when seeking to grasp an object guided by the image reflected in a mirror (mirror ataxia). Furthermore, this investigation made it clear that neither hemineglect nor right parietal lesions are necessary conditions for mirror agnosia; mirror agnosia thus constitutes a specific syndrome.

Neglect behavior is characterized by disorders in recognizing and using space. Unilateral spatial neglect can affect not only physical, personal or extrapersonal space, but also imagined space [3,5]. Many theoretical explanations have been put forward for neglect. These explanations can be differentiated into two issues, the first being the level of processing at which the critical deficit is postulated to occur (attentional, representational,….) and the second being whether the deficit is understood as a failure of the right hemisphere or the exaggerated influence of the left hemisphere. Ramachandran et al. [18] believes that the use of a mirror might provide a new approach for the treatment of visual neglect. The mirror seems to enhance patients’ awareness of the neglect field, so they correctly reach for an object shown in the neglect field.

In the present study, hemineglect subjects were asked to grasp and displace objects with their upper limb, using a normal mirror and an inverted mirror for guidance. When they looked at a normal mirror, these patients neglected the contralesional space, grasping correctly objects in the ipsilesional space. When they looked at an inverted mirror, they neglected the ipsilesional space, grasping correctly objects in the contralesional space. It appeared as if the mirror-image nature of the visual information was recognized and the processing necessary to grasp the object, guided by the reflected image, proceeded normally. There was, however, a dissociation between the physical space, or more precisely the ‘used’ space corresponding to the left or the right space depending on the experimental condition (normal mirror or inverted mirror), and the reflected space which remained the same (right side) in both experimental conditions. Our hypothesis is that hemineglect patients experience difficulty in generating new spatial representations due to their inability to adapt perceptive-attentional procedures necessary to manipulate mirror-image information. This inability would be related to defective processing of ‘non-mirror-image’ clues.

2. Materials and methods

2.1. Patients and controls

The reference population was four right-handed patients with neglect syndrome – patients 1, 2, 3 and 4 – who were included after attending a neurorehabilitation clinic between April and December 1999. Magnetic resonance imaging (MRI) or computed tomography (CT) scan had confirmed the existence of an ischemic lesion in the area of the right or left middle cerebral artery (n = 3) and of the posterior cerebral artery (n = 1). Subjects with behavioral disorders and/or cognitive impairment were excluded. Four right-handed subjects matched for education and age and with no neurological history comprised the control population.

2.2. Neuropsychological testing and assessment

All the subjects were tested by the same investigator. Unilateral spatial neglect was assessed with visual tests and mirror tests – Diller’s test [7], drawing a clock, line bisection test [12] Bell’s test [8], and copying a scene [16]. Scores of unilateral spatial neglect were based on the results of Diller’s test interpreted using the criteria determined by Seron and Laterre [23]. The investigator asked each subject to draw his own body on a piece of paper, searching for right/left indistinction, autotopoagnosia or digital agnosia. The scores were rated symptom present or absent.

2.3. Mirror experiments

Two mirrors were used, a normal mirror (w = 0.85 m, h = 1.54 m) and an inverted mirror (w = 0.5 m, h = 1.52 m, depth 0.355 m, angle 90°) specially designed for the study (Fig. 1). The inverted mirror used the principle of double reflection: two mirrors were placed perpendicular to each other. The image was inverted by the first mirror then re-inverted by the second. The subject sat facing the mirror (d = 0.6 m between the eyes and the external border of the mirror) and looked
into the center of the mirror (placing the mirror in front of the patient in the coronal plane). The two tests were performed with the ipsilesional upper limb. The investigator checked the relative position of the eyes and the mirror. Patient performances were recorded with a video camera and evaluated off line.

Sixteen red, blue, green and yellow cubes (w = 0.03 m) were placed horizontally on the table in two parallel lines of eight cubes each, in a precise color order. The distance between the cubes was about 8 cm horizontally and 10 cm from front to back. A box (w = 0.370 m, d = 0.7 m, h = 0.145 m) which was open in the front and the back was placed over the cubes so the subject could not see them directly. The subject was asked to grasp the cubes while looking at them in the mirror. The subject was to grasp the cubes in a precise order, red cubes (n = 4), blue cubes (n = 4), green cubes (n = 4), and finally yellow cubes (n = 4), before putting them on the upper surface of the box. The investigator noted the number of tries and the order the cubes were grasped.

2.4. Analysis of the video recording

Detailed analysis of the performance of patients and controls while doing the task was made by examining the video recording running in slow motion. The following criteria were used to evaluate patient performance: (i) direction of the arm movement during the initial phase of the movement, (ii) number of corrections of the position of the right or left hand before grasping.

3. Results and observations

3.1. Epidemiological characteristics and lesion localization

There were three men and one woman (mean age 49.5 years; age range 37–53 years) in the control group. There were also three men and one woman (mean age 54.5 years; age range 45–67 years) in the test group. Mean delay between the stroke and the tests was 4 months. Three patients suffered an infarction of the middle cerebral artery: both superficial and deep in one case and superficial or deep in the other two. One patient had an infarction of the right posterior artery. (Fig. 2).

3.2. Neuropsychological features

Spatial neglect was found in all the patients. Lack of right–left distinction and autotopoagnosia were not present. One patient (patient 4) had digital agnosia. Disorders of the body image were severe in all patients. On copying a drawing [16], patients 2 and 3 omitted half of the house while they correctly reproduced the tree on the extreme left of the picture. Patient 1 omitted the left half of the house and the tree on the extreme left. Patient 4 (right neglect) omitted only the tree on the extreme right. The main characteristics are shown in Table 1.

3.3. Grasping objects presented through mirrors

Facing the mirror, the controls grasped all the cubes in the requested color order in both experimental conditions (normal mirror and inverted mirror). All of the hemineglect patients grasped the cubes in an anachronous order and did not respond to a right–left versus left–right and/or front–back versus back–front orders. The number of cubes grasped ranged from 8 to 14 (there were a total of 16 cubes). All the cubes grasped were placed on the upper surface of the box. In the normal mirror condition, left hemineglect patients did not grasp or only partially grasped cubes situated on the left side of the table. When using the inverted mirror, these same patients did not grasp cubes on the right side of the table. The patient with right hemineglect did not grasp or only partially grasped the cubes on the left side of the table when using the inverted mirror. With the normal mirror the omission for this patient concerned those on the right side of the table and with the inverted mirror the cubes on the left side. This patient with right neglect omitted fewer cubes than the patients with left unilateral spatial neglect. None of the patients criticized the modifications in their grasping behavior.

3.4. Analysis of the video recording

The video recordings showed that, during the initial phase, when guided by the inverted mirror, the controls directed their arm directly to the real object. Before grasping the cubes, some of them implemented few corrections i.e. changes in the position of the hand (horizontal or vertical – mean: 1–2) and very short horizontal displacements correcting the direction of the real object-centered hand movement. The hemineglect patients were not able to reach toward directly the real object as long as it was presented into the mirror. During the initial phase, the patients directed their arm to the left (or right) cubes without attempt to correct the movement path. They made several large horizontal displacements of the ipsilesional upper limb (mean: 2.5) in the ‘healthy’ space and/or in the neglected space before grasping (sweeping the used space right to left then back again). Furthermore, they did not try to correct the position of their hand.

The controls used ‘clues’ i.e. the ability to make use of proprioceptive information provided by active move-
ments. Neglect patients were not able to conceive the direct movement trajectory and therefore looked for other points of reference or approached the target by trial and error. They do not use the same clues.

4. Comments

According to the representational hypothesis, the neglect syndrome is due to a degradation of an inner representation of the hemispace. Our paradigm is close to that used in mental representation tests (the ‘Piazza del Duomo in Milano’, ‘map of France’ [21]). We changed, however, the source of the visual information. In mental representation tests, the selected information concerns half of the mental image. In our study, the selected information concerned half of the presented space but as reflected in a mirror. In addition, the inversion of the space is virtual during the mental representation tests. It was real and dissociated in our paradigm because it only concerned the physical space or the used space, while the reflected space remained
unchanged (right side). Several experiments have been designed to demonstrate directional hypokinesia. Many authors suggest that the anterior lesions can be associated with ‘intentional’ neglect while the posterior lesions lead to ‘attentional’ disorders [4,6,15,24]. Using two mirrors, we were able to uncouple the movements of the ipsilesional upper limb from the direction of the visual attention of the hemineglect patients. The patient’s visual attention was directed to the right in both response conditions. In all cases, patients had no difficulty in moving their arm into left or right ‘physical’ space. None of them showed an unambiguous hypokinetic behavior or a perceptual pattern alone. Tegner and Levander [24] reported this kind of dissociation and suggest that their ‘patients (n = 10/18) suffered from directional hypokinesia of eye movements but not of arm movements’. This would be less plausible in our patients because of the way they copied a drawing [16]: patients 2 and 3 omitted the half of the house while they correctly reproduced the tree on the extreme left. Patient 1 omitted the left half of the house and the tree on the extreme left. Of course, our results must be regarded with caution: the material is small and the brain damage was extensive, except for patient 4 who had a unique posterior lesion.

The results of our work do not favor a right–left distinction disorder: our patients did not exhibit right–left indistinction nor autotopoagnosia.

The normal controls used perceptivo-attentional procedures, which differed depending on the nature of the mirror image information, allowing them to construct adapted representations. In children, acquisition of a visual image of oneself, a representation of one’s own body (‘self image’ or ‘mirror image’) is achieved by use of mirrors. The child starts by seeing his/her own image as a sort of double of his/her own body between physical ‘interoceptive’ space and ‘image-inherent’ space. Progressively, the child moves the ‘self image’ in the virtual ‘mirror’ space into the physical space of his/her own body. This mirror image is the only complete visual information one has of one’s own body. Later, the use of a normal mirror in everyday life requires a learning process, implicating perceptivo-attentional and motor capacities which are rapidly adapted and automatized. With the inverted mirror, the controls used ‘non-mirror-image’ clues derived from changes in the position of the hand and short horizontal displacements correcting the direction of the real object-centered hand movement before grasping. Other clues, particularly attentional clues, could also be used. There is evidence that the hemispheres differ in terms of the ‘spatial scale’ at which they prefer to operate. The left hemisphere is specialized for ‘focal’ perception and the right hemisphere for ‘global’ perception [20,22]. Umilta [25] and Laberge and Brown [13] developed a ‘zoom-lens’ model based on the notion of an ‘attentional spotlight’ with a variable beam diameter. With this model, the left hemisphere attempts to reduce (focalize) the diameter of the attentional spotlight and the right hemisphere attempts to increase its size [19]. Normal subjects are thus able to ‘modulate’ the direction of the visual attention, using a ‘panoramic’ or a ‘focal’ mode.

Hemineglect patients do not use the same clues, and thus do not modify their procedures as they do not have the possibility of recalibrating the different representations. These differences concern non-mirror-image clues and directional and positional as well as atten-

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<tr>
<th>Patients</th>
<th>Left neglect</th>
<th>Right neglect</th>
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<tbody>
<tr>
<td></td>
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<td>Patient 2</td>
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<td>M</td>
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<td>F/T/P</td>
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<td>Time since stroke (month)</td>
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<td>2</td>
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Neglect results

- Diller’s test: ++++, very severe; ++++, severe; ++, slight; absent.
- Copying a drawing: 3, omission of the entire tree on the R or L; 2, omission of the R or L half of the house; 1, omission of the R or L window; 0, reproduction without omission.
- Autotopoagnosia: 0, reproduction without omission; 1, omission of the R or L window; 2, omission of the R or L half of the house.

* F, frontal; T, temporal; P, parietal; O, occipital. Scores in (a) Diller’s test: 0, absent; +, slight impairment; ++, moderate impairment; ++++, severe impairment. (b) Copying a drawing: 0, reproduction without omission; 1, omission of the R or L window; 2, omission of the R or L half of the house; 3, omission of the entire tree on the R or L. (c) Digital agnosia, autotopoagnosia, R/L indistinction: scores were rated symptom present (+) or absent (−).
tional vectors. Marshall and Halligan [14] hypothesized that ‘the combination of two independent properties of normal hemispheric functioning (contralateral direction and the focal/panoramic distinction) should predict much of the symptomatology of left visual neglect after right hemisphere lesion’. Damage to the right temporoparietal cortex should impair global attention, allowing the rightward orientational bias of the intact left hemisphere. Focal attention will thus be directed strongly rightward. When copying a drawing, patients 2 and 3 omitted half of the house while they correctly reproduced the tree on the extreme left. Patient 1 omitted the left half of the house and the tree on the extreme left. These results are consistent with the dual-attention analysis and were intermediate between the pure global feature and the pure focal feature. The patients thus no longer had the possibility of ‘modulating’ the direction of their visual attention as a function of the task to be accomplished. The case of patient 4 (right neglect) is probably different: he omitted only the tree on the extreme right. But patient 4 had digital agnosia. Other disorders could be involved in the case of patient 4 who may have had an impaired perception of modifications of the position of his hand.

5. Conclusion

Examining the way subjects interpret mirror images provides a new approach to a better understanding of the neural representation of mirror images in the brain. Responding correctly to a mirror image requires creating a ‘rather peculiar form of dual representation or mental diplopia’ which can be altered by parietal damage [17]. In addition, neglect behavior is also described using spatial reference conditions, self-centered or object-centered co-ordinates [11,20]. Dissociation between left neglect for personal and extrapersonal space [9] and left neglect for near but not far space and vice versa have also been reported [10,26]. These dissociations after different lesions would support the claim of distinct representations for ‘mirror image or space’ in humans. The normal subject codes the different ‘reference co-ordinate systems’ by using different parietal modules. However, most of the lesions affects fronto-parietal-occipital areas. These data show that these dissociations occurs in patients with damage to other parts of the brain. Further studies are needed to clarify mirror neglect, the roles of temporal lesion and analyze the place this technique could have in treatment [1,18] of unilateral spatial neglect.

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References