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Perceiving an entire object and grasping only half of it

Umberto Castiello [a,b,*], Mark Paine [b,c], Roger Wales [d]

[a] Department of Psychology, Royal Holloway, University of London, Egham, Surrey TW20 0EX, London, UK
[b] Department of Clinical Neuroscience, St. Vincent's Hospital, Melbourne, Australia
[c] Neuro-Ophthalmology Clinic, Royal Victorian Eye and Ear Hospital, Melbourne, Australia
[d] Faculty of Humanities, La Trobe University, Bundoora, Australia

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Abstract

A single case study is presented of an unusual dissociation between the sensory perception of an object and the grasping action towards the same object. The patient IW was found at age 74 to have spent all his life without the left parietal lobe, as a result of a congenital peri-natal insult. IW does not show any signs of sensory dysfunction, but he has a persistent motor bias that arises during movement towards objects. When IW was required to reach and grasp stationary and rotating objects, he consistently grasped the objects to the left side. Thus, it appears that information that is available at a sensory level can nevertheless be unavailable at a motor level. Our findings not only help to clarify the functions of the parietal lobe, but also show that lesions in this area are linked specifically to a process of response performance, which is fundamental for our understanding of visuomotor control. © 2001 Elsevier Science Ltd. All rights reserved.

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1. Introduction

The aim of the present study is to investigate perception and action dissociation following left parietal lesion. We employed reach to grasp kinematics as an experimental window to measure the performance of a subject (IW) with a left parietal lesion. This task was chosen for IW to perform as it could provide further information on the role of the left parietal lobe in motor control [7] and motor representations [5]. For the motor control side, impairments in the kinematics of movement have been reported in some patients with left parietal lesion [11] and in monkeys with lesions of parietal areas 5 and 7b [12]. Further, recent PET studies also showed activation of the left inferior parietal cortex when subjects prepared to move one of their fingers [3,8,13]. Left inferior parietal activation was found for both the right [3,8] and the left hand [13]. For the motor representation side, neuroimaging studies have shown that the left parietal lobe is involved during the perception of objects when subjects prepare to act [5]. Other studies have suggested that this region codes for a general class of grasping action representations which are independent from movement execution [2,5].

In line with the findings of impairment in motor control and motor representation after lesion of the left parietal lobe, subject IW shows a persistent motor bias that arises during movement towards objects. When IW is required to reach and grasp a stationary or a rotating object, he consistently grasps the object to the left side. In contrast, he can perfectly perceive the object in its entirety from a purely perceptual point of view. As previously reported for patients with optic ataxia [9] and visual form agnosia [9], there appears to be a dissociation between information available at a sensory level and information available at a motor level.

* Corresponding author. Present address: Department of Psychology, Royal Holloway, University of London, Egham, Surrey TW20 0EX, London, UK. Fax: +44-1784-434-347.

E-mail address: u.castiello@rhul.ac.uk (U. Castiello).

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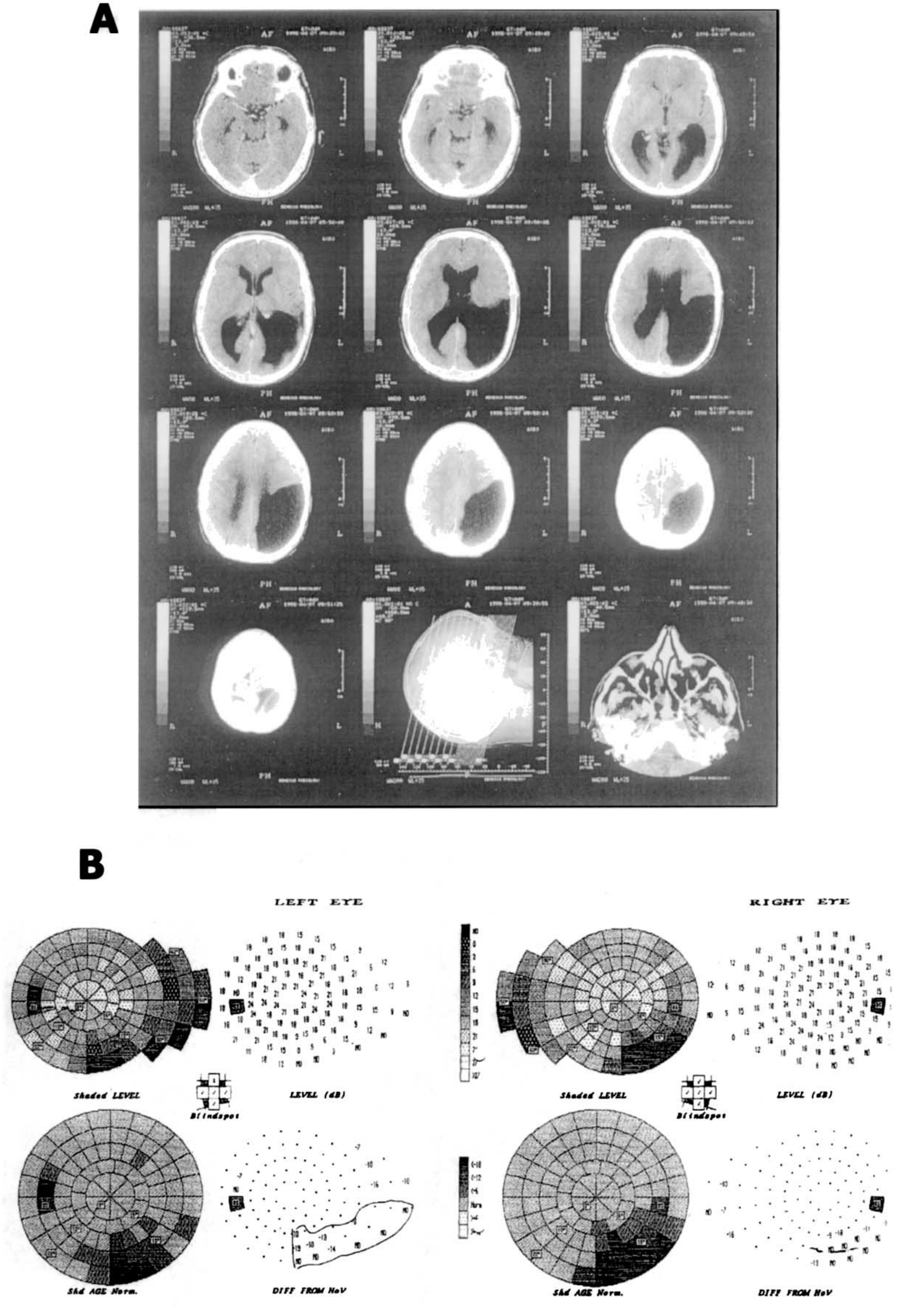

Fig. 1. Panel A: The CT scan shows a large area of porencephaly almost obliterating the parietal lobe on the left (the left hemisphere is shown on the right side of the image). The medial portion of the occipital lobe and occipital pole are preserved. Panel B: Automated perimeter for the left and the right eye.

2. Methods

2.1. Case history

IW, a 74-year-old left-handed man, was found to have an incomplete right homonymous hemianopia during the evaluation of glaucoma. A CT scan unexpectedly revealed a large area of porencephaly almost totally obliterating the left parietal lobe, which was most likely to have been sustained as a result of perinatal insult (Fig. 1, Panel A). An automated perimeter (see Fig. 1, Panel B) shows that the field defect was quite subtle to confrontation — a homonymous inferior sector aligned to the vertical meridian.

2.2. Neuropsychological examination

Administration of the Wechsler Adult Intelligence Scale — Revised revealed a full scale IQ of 81, with a verbal IQ of 81 and a performance IQ of 84. This placed his IQ in the 'borderline to low average' range. He also performed within normal limits on tests of verbal and visual memory (Rey Auditory Verbal Learning Test; Rey Complex Figure Test; Logical Memory and Verbal Paired Associates from the Wechsler Memory Scale — Revised). His only significant impairment was on a task requiring him to generate words beginning with a given letter. Visuo-perceptual function was found to be intact (as measured by Foreshortened Match, Length Match, Minimal Feature Match and Picture Naming from the Birmingham Object Recognition Battery). IW was able to copy both simple and more complex figures and draw from memory. He was also able to recognise and name pictures of familiar objects. There was no evidence of ideomotor or ideational apraxia. Furthermore, no evidence of neglect was found on line bisection tasks, cancellation tasks or copying tasks. IW was also checked for extinction by using an extinction task where unilateral and bilateral stimuli, with catch trials interspersed, were presented. No extinction was found. A control subject matched for age, gender and handedness was also tested. The control subject reported no neurological or skeletomotor dysfunctions.

2.3. Stationary object motor task

IW and the control subject were seated at a table (50×90 cm). The target was a red wooden cylinder (length 10 cm, diameter 1.2 cm) which was laying horizontally 30 cm from the starting position (see Fig. 2). The target could be positioned to the right, center or left of the starting position (see Fig. 2). The starting position and initial hand posture remained the same during the experiment. Visual availability of the stimuli was controlled with Plato spectacles. These were lightweight, and were fitted with liquid crystal lenses. The opacity of the lenses was controlled by the com-

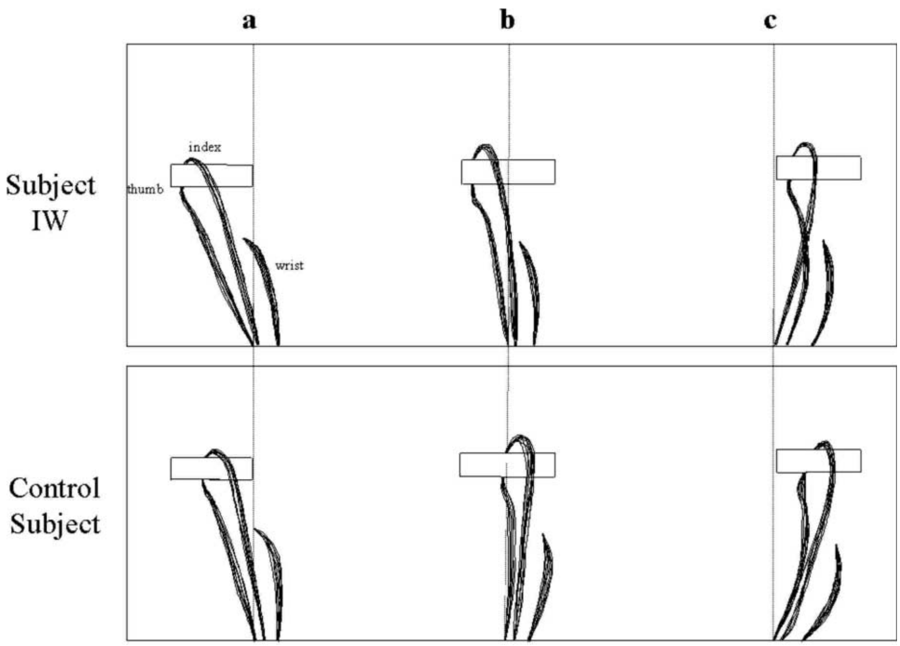

Fig. 2. Spatial paths (X–Y) executed by IW and the control subject for movements directed towards a target presented ipsilaterally (panel a); midsagitally (panel b) and contralaterally (panel c). For IW the hand contralateral to the lesion (right hand) is represented. The same hand is presented for the control subject.

puter. The lenses were opaque at the beginning of each trial. When the lenses cleared the subjects had to reach towards and grasp the cylinder. The lenses remained clear until the end of the grasping action. This task was performed with the right and the left hands in separate blocks. Within each block, the cylinder's position was randomised. IW and the control subject performed 10 trials for each hand/cylinder position combination, for a total of 60 trials. They were asked to perform a natural, unspeeded grasp. Body, head and eye movements were in no way constrained.

2.4. Rotating object motor task

The object was positioned on a rotating table moving at 50, 100 and 150 rpm, 30 cm from the starting position on the subject's midline. The lenses of the PLATO spectacles were open at the onset of object rotation and closed after the object was grasped. The object could start to rotate in either a clockwise or a counter-clockwise direction. IW and the control subject were required to start moving as soon as the spectacles cleared. IW and the control subject performed 10 trials for each hand/rpm combination. As for the stationary task body, head and eye movements were in no way constrained.

2.5. Sensory tasks

In the first task, IW and the control subject were asked to verbally identify white tags (0.8×0.5 cm) positioned on either the right, center or left sides of the cylinder used for the motor task. The cylinder itself could be positioned on the left, right or center with respect to the subject's midline. In particular, subjects were required to say 'right', 'center' or 'left' depending on where the tag was positioned. Vocal reaction times (VRT) were measured as the interval from the clearance of the shutter glasses lenses and the first detectable vocal signal.

In the second task, IW and the control subject were asked, after the clearance of the shutter glasses, to match the size of the cylinder (no tags were put on the cylinder) by opening their fingers but without actually performing the reaching action. As for the motor task the object rested horizontally on the table and was positioned on the left, right, or center with respect to the subject's midline. The distance between the subjects and the object was the same as for the motor task (30 cm). For the first sensory task the order of the cylinder and tag positions was randomised. IW and the control subject performed 10 trials for each cylinder/tag position combination. For the second sensory task the order of the cylinder position was randomised. IW and the control subject performed 10 matching trials for each cylinder position.

2.6. Data processing

Movements were recorded with the ELITE motion analysis system (see [1] for details). The subjects wore three markers attached to: (a) the wrist (the radial aspect of the distal styloid process of the radius); (b) the index finger (the radial side of the nail); and (c) the thumb (ulnar side of the nail). $X-Y$ spatial trajectories of the wrist, index finger and thumb markers were computed. Further, the variability of the spatial paths over repetition of the same movement was also calculated. It was deemed important to control for this measure because it provides an important index of movement pattern stability. Spatiotemporal variability of the wrist, thumb and index trajectories was quantified after time normalization of the data. The standard deviations of the mean X and Y positions of each marker were calculated for each of the 100 normalised time frames. In addition, to obtain a global estimate of variability (index of variability) for the three markers, the surface area of the ellipses defined by the standard deviations in X and Y dimensions was computed (in cm^2), and the values of these surfaces in each frame were pooled [4]. The temporal pattern of hand aperture was assessed by analyzing the distance between the markers positioned on the index finger and thumb.

3. Results

3.1. Sensory tasks

In regards to the sensory tasks both patient and control subject performed the tasks effortlessly. For the first sensory task an analysis of variance with Subject (IW and Control), Tag Position and Cylinder Position as factors revealed that VRTs for IW and the control subject were similar independent of the tag and the cylinder position (see Table 1). For the second sensory task an analysis of variance with Subject (IW and Control) and Cylinder Position as factors revealed that finger aperture for IW and the control subject were similar independent of the cylinder position (see Table 1). No differences between the two subjects were found. Both subjects were able to appropriately match the cylinder's size in its entirety. However, because only one target size was utilised an alternative interpretation for the results concerned with this task is that IW learned the size of the one target presented and developed a stereotypical response.

3.2. Stationary motor task

When performing grasping actions towards three-dimensional objects, IW ignored information on the

Table 1
Mean vocal reaction times and finger aperture for IW and the control subject for the two sensory tasks[a]

Cylinder position	Left			Centre			Right		
Tag position	Left	Centre	Right	Left	Centre	Right	Left	Centre	Right
Vocal reaction times (ms)									
IW	565 (63)	573 (67)	559 (61)	563 (59)	563 (65)	571 (67)	561 (59)	576 (62)	555 (64)
Control subject	538 (55)	547 (62)	543 (59)	561 (60)	558 (60)	557 (64)	559 (63)	560 (61)	566 (58)
Finger aperture (cm)									
IW	11.00 (2)	11.3 (3)	12.00 (3)	11.1 (4)	12.4 (3)	11.5 (3)	11.6 (2)	11.6 (3)	12.6 (4)
Control subject	11.5 (2)	12.7 (3)	11.6 (4)	12.00 (3)	11.8 (2)	11.5 (3)	12.00 (3)	11.5 (2)	12.5 (2)

[a] SD in parentheses.

right, thus showing a left-sided grasping bias. The results demonstrated that IW reached towards and grasped the object on its left side on 99% of occasions (see Fig. 2) with both the right and the left hand. The control subject consistently grasped the cylinder approximately in the centre at all times (see Fig. 2). As can be seen from the finger trajectories in Fig. 2, IW and the control subject used a typical grasp configuration, gripping the object from the top with their opposing index finger and thumb. The index of variability for IW and the control subject were similar and did not differ with respect to the position of the cylinder. As an example, for IW the index of variability was 221, 478 and 565 cm^2 for the wrist, index finger and thumb, respectively for reaching towards the cylinder placed in the midsagittal position. For the control subject the index of variability for the same cylinder position was 235, 504 and 578 cm^2 for the wrist, index finger and thumb, respectively. The index of variability values for the ipsilateral and contralateral cylinder positions were similar to the values reported above. For both patient and the control subject variability was not evenly distributed along the trajectory. It increased from the start to half of the trajectory and then decreased at object contact. Variability was highest at 37 and 35% of the entire movement duration for IW and the control subject, respectively. The low variability at the end of the movement suggests that the fingers contacted the object at the same points over movement repetitions.

3.3. Rotating motor task

In the rotating session IW always waited for the object to be in an orientation such that it could be comfortably grasped on its left side. This was achieved either through a speeding up of the grasping action, or through varying the length of ‘waiting’ phases along the grasping action (see Fig. 3), depending on which hand was used and which direction the object was rotated. For example, if the object started to rotate clockwise at a high speed and the right hand was used, IW speeded up his grasping action in order to grasp the cylinder in a position perpendicular to his body axis. In contrast, for the same condition when the object rotated at a slower speed, IW started to open his hand after the signal for movement onset was given, then stopped the action until the object reached a specific position. This waiting phase was directly related to the speed of rotation (see Fig. 3). For IW the average time from the moment that index finger and thumb stopped the opening phase and the moment when they restarted the opening phase was 363, 193 and 96 ms for the 50, 100 and 150 rpm conditions, respectively. The waiting phase was noticed in all occasions. The control subject did not show any ‘waiting’ phase.

4. Discussion

The experiments presented here seem to provide evidence for dissociation between sensory perception and action. However, although this seems to be a reasonable inference, the discussion that follows is made with great caution because we are aware that peri-natal prosencephalic cysts can induce massive rearrangements of connections. Probably this occurred in IW who shows a strikingly mild deficit compared to the size of the tissue loss.

The present study supports the idea that the human parietal lobe is concerned with visuomotor control [2,6]. The left motor bias observed in IW was not due to his right visual field defect. As can be seen from the automated perimeter presented in Fig. 1 this possibility is rather unlikely. Further, even though he grasped the object always to the left, the grasping action was performed appropriately. As an example, IW did not show a significant increase in the index of variability. He suitably planned the hand paths to minimise variability at the end of the movement. The low terminal variability indicates that the fingers tended to contact the object at the same points to the left on each repetition of the movement as classic performance for a reach-to-grasp task would predict [10].

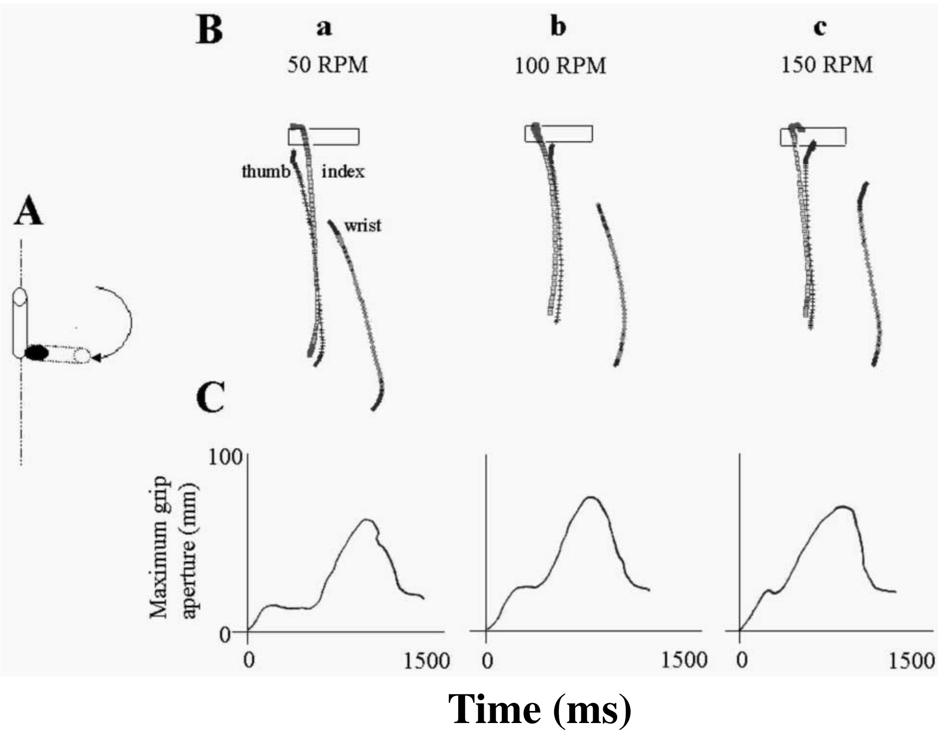

Fig. 3. Panel A: Example of cylinder clockwise rotation. The cylinder drawn with solid lines represents the cylinder at starting position, while the cylinder drawn with dashed lines represents the cylinder at the moment it was grasped. The black part of the object represents where the object was grasped. Panel B: Spatial paths ($X-Y$) executed by IW for movements directed towards the cylinder rotating in a clockwise direction at 50, 100 and 150 rpm. Panel C: Grasp profiles calculated from the beginning of the reaching action to the end of the grasping action.

At this stage we are inclined to suggest that the present results may be more related to the proposed role played by the left parietal cortex in the preparation of selected movements [3,8,14]. In particular, the type of dissociation we have observed in IW seems to allow speculations regarding an asymmetrical motor control system concerned with the preparation of hand action which is independent from object sensory perception. Recent neuroimaging studies have pointed out a role of the left inferior parietal lobule not only for motor planning but also for the coding of affordances [2,5]. The basic idea is that the left inferior parietal lobe is concerned with the encoding of motor behavior at representational level where the general class of hand shape required to interact with objects is specified. Along these lines, IW's motor bias may be at the representational level. That is, the link between the perception of the object and the routines necessary for the interaction with the object are dysfunctional. In these terms, the fact that the performance on the sensory tasks is not affected is because the perceptual system is not closely associated to any particular effector system.

The case of IW also allows speculations regarding the limits of the compensatory functions carried out by the right parietal lobe. In general, the right posterior parietal cortex (PPC) duplicates partially the spatial functions of the left PPC for the right hemifield. Thus, we would have expected that the intact right parietal lobe of IW might have played a compensatory role. However, it seems that, even though these compensatory functions are available for perception, they are not available for the perception-for-action system. From a purely sensory point of view, IW reported that he perceived the object in its entirety but evidently this perception was only partially available for action.

In conclusion, our findings not only confirm previous observations of a dissociation between perception and visuomotor control [9], but also help to clarify the functions of the left parietal lobe showing that lesions in this area are linked specifically to a process of response performance, which is fundamental for our understanding of the perception for action system.

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