Unilateral Neglect and the Structure of Space Representation

Edoardo Bisiach

Lesions of particular districts of one side of the brain—most often, and for reasons that are still unclear, the right side—entail neglect of the opposite (contralesional) side of egocentric space.[1] Patients usually behave as if the neglected side did not exist, indeed, as if it had never existed. They neglect not only what is contingently located on the contralesional side of external objects or stimulus arrays, but also what is inseparably bound to that side, namely, contralesional body parts. Patients, for example, not only fail to take food from the left side of the plate, they also leave the left side of their face unshaved or the left side of their bodv undressed.

NEGLECT AS A DISORDER OF SPACE REPRESENTATION

With a few notable exceptions, the involvement of the high cognitive level of brain activity in the causation of unilateral neglect was long disregarded. Failure to perceive the contents of the contralesional side of external or bodily space, and—much more questionably—lack of exploration of that side, seemed to be amenable to more parsimonious explanations in terms of relatively peripheral impairment of perceptual or attentional mechanisms.

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The involvement of very high level brain activity in unilateral neglect, however, was later demonstrated by patients' failure to describe from memory the contralesional side of familiar surroundings as imagined from a given vantage point. I first met with this amazing phenomenon while examining N.V., a lawyer who was struck by a right temporo-parietal hemorrhage and consequently suffered from left neglect. When asked to describe his office as it appeared to him while sitting at his desk, he gave a remarkably poor report of the office's left side. This was in sharp contrast with the richness of the details he supplied with regard to that same side when asked to redescribe the room from the opposite perspective, so that the earlier neglected side was located on his right. Among the recovered details were a piano of which he was very fond and old paintings and tapestries upon which he dwelt while largely disregarding the opposite (formerly more thoroughly described) side.[2]

It is evident that this case rules out impaired processing of (and orienting toward) external stimuli as a source of neglect phenomena. It is also evident that there was no memory loss. N. V.'s behavior may therefore be viewed as a disorder of space representation, if by this term we mean the ability to mentally reconstruct systems of coordinates (spatial frames) within which the spatial relationships of (perceived, remembered, or imagined) objects with respect to each other and the subject are organized so as to be properly described or acted upon. More particularly, N.V.'s disorder affected the left-right dimension of the frame adopted for recall and description of his office in such a way that details falling, according to the assumed perspective, on the left side of that frame were omitted.

A similar conclusion may be drawn from neglect patients' failure to consider the left side of shapes moving, righrward or leftward, behind the vertical slit of a screen occluding the whole shape except for a narrow strip. When asked whether two such shapes (shown one after the other) were the same or different, neglect patients correctly answered "different" if the critical detail was located on the right side, but "same" if, as in Figure 1, it was located on the left.[3] Because all portions of each shape were presented on the axis of gaze, the portions that were neglected in giving same/different judgments were defined only by reference to the mental reconstruction of that shape. In fact, there is no way to determine whether a given detail of an object's shape belongs to its left or its right side without taking the entire shape into account.

Further investigations extended the implications of these early findings. The inability of left-neglect patients correctly to spell,

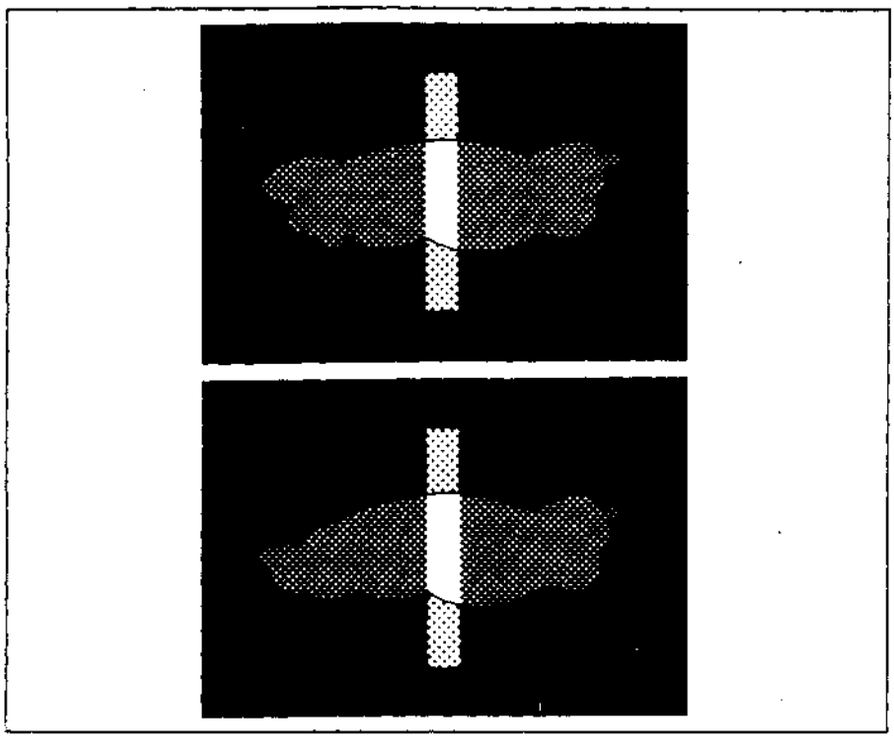

Fig. 1. Example of stimuli used to test neglect patients' ability to judge two shapes shown while moving behind a slit as the same or different. Reproduced by permission from Bisiach and Berti.[4]

forward or backward, the first (leftmost) letters of words,[3] or to deal with left turns in describing familiar routes,[6] shows that failure to represent from memory the contralesional side of space may also affect verbal items and is not confined to stationary perspectives externalized, as it were, over a virtual screen for further inspection. In these instances, too, the topological properties of the patient's failure arise from the left-right polarity in the coordinate system in which objects or scenes are statically or kinematically framed by the subject in order to perform the required task.

On the basis of these findings, it has been argued that space representation in the brain, rather than being symbolic, is topological. Damage of one side of the brain, ndeed, impairs representation of :he opposite side of viewer-related space in the same way as represenation of upper or lower space may ?e impaired by bilateral brain damage, depending on whether the lesion is more ventrally or more dorsallv located/

THE SPATIAL FRAMES OF NEGLECT

Which coordinate framework defines the left-right polarity within which neglect occurs? As shown in Figure 2, what is "to the left" in one coordinate framework is "to the right" in another, and because experimental findings show that coordinate frameworks interact, there is no single answer to this question.

For example, in one experiment,[8] left-neglect patients were required to extract, without visual control, pegs from holes distributed over a stimulus array. Patients kept their eyes open, but the stimulus array was covered by a cloth. There were four conditions (schematically shown in Fig. 3): Condition A, stimulus array and line of sight aligned with the trunk's sagittal midplane; Condition B, stimulus array alone to the right and line of sight aligned with the trunk's sagittal midplane; Condition C, stimulus array and line of sight both to the right; and Condition D, line of sight alone to the right and stimulus array aligned with the trunk's sagittal midplane. If the deficit is eye-centered, one" would expect to find neglect of one side of the display in Conditions A and C, in which the line of gaze goes through the middle of it, but not in Conditions B and D, because the whole display appears either on the right (B) or on the left (D) of the line of gaze. If the deficit is trunk-centered, patients should show neglect in Conditions A and D only. Interestingly, neglect was actually found in Conditions A, C, and D, thereby demonstrating that the deficit may be at the same time ; eye- and trunk-centered.

Neglect may relate to a perceptual array or a complex object as a whole, or to single perceptual

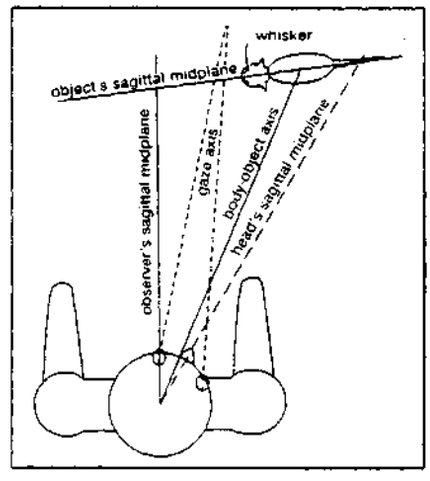

Fig. 2. Different axes and planes with respect to which left-right may be defined. The one lone whisker sticking up from the top of one side of the creature's head is to the right of the sagittal midplane of the observer's trunk, to the left of his or her head's sagittal midplane, to the right of the gaze axis, to the left of the body-object axis, and to the right of the object's sagittal midplane.

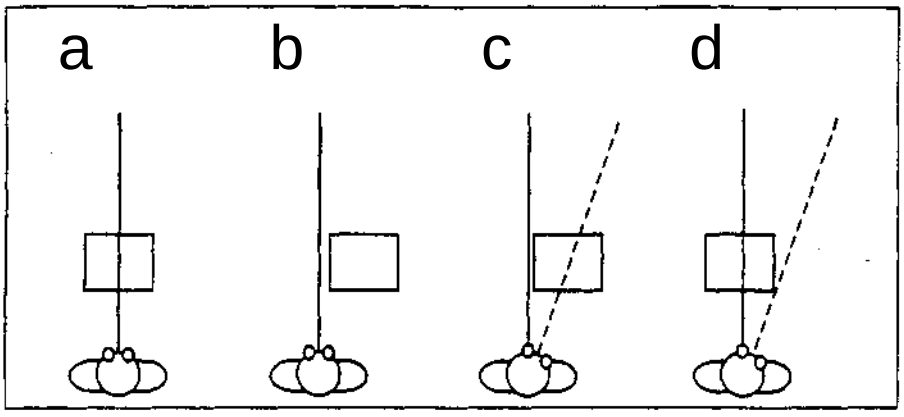

Fig. 3. The four experimental conditions for the peg experiment. See the text for details.

units within that array or object. A recent example is the following. Left-neglect patients were asked to copy a drawing with two flowers in two different conditions: In the first condition, the flowers originated from a common stem; in the second condition, the lower part of the model was deleted, so that the two flowers appeared as independent objects. Some patients altogether omitted the left flower in both conditions, whereas other patients omitted the left flower in the first condition but the left-side details of each flower in the second.[9]

These examples are meant only to give the reader an introduction to a problem that includes issues such as the role of gravitational coordinates, the distinction between proximal (near) and distal (far) frames of spatial reference, and the gradient of neglect (continuous vs. stepwise). Further complication is due to the likely differential involvement of mechanisms acting nearer to the input or to the output end of sensorimotor processing. It has been suggested that in some cases neglect may be due to a premotor disorder impairing preparation and execution of movements toward the side contralateral to the brain lesion. This is, however, an extremely tricky issue that is still far from being resolved. A review of these issues may be found elsewhere.[7]

CONTRALESIONAL NEGLECT VERSUS CONTRALESIONAL MISREPRESENTATION

Much progress has been made since cognitive psychologists and neurobiologists became interested in unilateral neglect as a means to understand the structure of space representation. Nonetheless, I propose that considering only defective symptoms shown by patients with unilateral brain damage (i.e., neglect, in the sense of lack of behavior on the contralesional side of space) is too restrictive. The phenomenology of neglect may suggest either a reduced size of the attentional field on the contralesional side or a reduced processing of information on that side, or both. Accordingly, neglect has been variously (and somewhat tautologically) interpreted as consequent upon impaired attention within the contralesional side of space, an ipsilesional (i.e., on the same side as the brain lesion) twist of attention, inability to disengage attention from ipsilesional stimuli, a contralesional loss of the medium for space representation, deviation of the self-centered frame of spatial reference toward the ipsilesional side, or a premotor disorder restraining movement toward the contralesional side of space. There are, however, productive symptoms (in the sense of contralesional abnormal behavior, to which the term neglect does not properly apply) that can hardly fit these interpretations.

The results of a recent investigation[10] exemplify the point. Left-neglect patients were asked to bisect a 15-cm horizontal line (the canonical line bisection task). As usual with such patients, they marked the subjective midpoint of the line to the right of its objective midpoint. They were then asked to set the endpoints of an imaginary line of that length with reference to its midpoint, marked by the examiner at the center of a sheet of paper. Patients misplaced both endpoints leftward! Their behavior thus yielded the very same disproportion resulting from the canonical line bisection task, in which the subjective midpoint was set nearer to the rightmost than to the leftmost end. In this case, however, such a disproportion can not be explained in merely defective terms: That is, it cannot be explained as being due to any of the factors just mentioned. Ongoing research demonstrates that what was observed in those two patients is an extremely frequent phenomenon, suggesting that in most patients with neglect symptoms, the left-right dimension is set on a logarithmic scale, as it were, with shrinkage (not amputation!) on the contralesional side and spatial expansion on the ipsilesional side. (This claim can be made less obscure by noting that if a horizontal segment is bisected with reference to a logarithmic scale, the midpoint would lie—according to a euclidean metric scale—nearer to the rightmost than to the leftmost endpoint of the segment, thus mimicking the usual bisection error made by neglect patients.)

This is a most important point. First, it emphasizes the represen-

tational nature of the disorder in question. Clearly, there is not a simple (lateralized) loss or decline of representational competence, but a left-right nonuniformity of the representational medium. Second, this account raises the challenging question as to whether such a distortion can explain by itself how contralesional information may be processed to a high cognitive level and nonetheless be neglected in the sense of being kept out of consciousness.[11] In other words, it is unclear that this kind of metric distortion can explain phenomena of contralesional misrepresentation such as the denial of unilateral motor impairment (anosognosia) and disownership of contralesional limbs (somatoparaphrenia).

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Notes

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