

Review

Dissociation of egocentric and allocentric coding of space in visual search after right middle cerebral artery stroke

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Abstract

Spatial representations rely on different frames of reference. Patients with unilateral neglect may behave as suffering from either egocentric or allocentric deficiency. The neural substrates representing these reference frames are still under discussion. Here we used a visual search paradigm to distinguish between egocentric and allocentric deficits in patients with right hemisphere cortical lesions. An attention demanding search task served to divide patients according to egocentric versus allocentric deficits. The results indicate that egocentric impairment was associated with damage in premotor cortex involving the frontal eye fields. Allocentric impairment on the other hand was linked to lesions in more ventral regions near the parahippocampal gyrus (PHG).

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1. Introduction

Patient studies have contributed many important insights on visual information processing and mechanisms underlying consciousness and awareness as impressively shown by Weiskrantz's research on blindsight (for an overview see Weiskrantz, 2004). Another common syndrome affecting conscious perception is neglect, since neglect patients behave as if (usually the left) part of the environment were nonexistent. These patients may accomplish personal hygiene only on one body-side, eat only from half of their plate or do not turn to their left side. More specifically unilateral neglect is defined as "the failure (or slowness) to report, respond, or orient to novel or meaningful stimuli presented to the side opposite a brain lesion, when this failure cannot be attributed to either sensory or motor defect" (p. 296, Heilman, Watson, & Valenstein, 2003). Neglect may be caused by cerebral lesions involving temporal (Karnath, Ferber, & Himmelbach, 2001), parietal (Mort et al., 2003; Vallar & Perani, 1986), frontal (Heilman & Valenstein, 1972; Husain, Mattingley, Rorden, Kennard, & Driver, 2000) or subcortical areas (Karnath, Himmelbach, & Rorden, 2002), particularly of the right hemisphere.

The astonishing changes of behaviour in neglect brought forth a large number of investigations on the underlying mechanisms and on the nature of visuospatial attention in healthy subjects. One fertile proposal of visuospatial information processing is that it may rely on at least two different frames of reference: egocentric and allocentric (for a review see Landis, 2000). Egocentric spatial representations of an object depend on the object's position relative to the viewer's body, such as trunk, head or eyes. In this frame of reference the terms left and right refer to the observer, therefore it is viewer-centered. Allocentric spatial representation on the other hand is a concept that includes representations of space both in object-centered and in stimulus-centered coordinates. Strictly speaking an object-centered representation requires an intrinsic object orientation (Marr, 1982). In this case the terms left, right, top and bottom refer to the object itself and are independent of the observer. Typical examples for objects with well-defined intrinsic directions are words. The easiest way to investigate the distinction between viewer-centered and object-centered forms of neglect is reading. Patients may miss whole words on the contralesional side of space (viewer-centered) or they may miss the contralesional letters of a single word independent of where the word is presented and even if it is presented reversed or mirror-inverted (object-

centred, Caramazza & Hillis, 1990; Hildebrandt & Ebke, 2003; Hillis, 2006). However, it is difficult to define strictly object-centered coordinates since most objects are not intrinsically orientated such as words are. Therefore a second concept of allocentric representation is the so-called stimulus-centered frame of reference, which is defined with respect to the observer's viewing position. Stimulus-centered neglect presupposes that patients omit features appearing on the contralesional side of objects even though they are presented on the ipsilesional side of the body (Hillis, 2006; Walker, 1995). It is often difficult to distinguish stimulus-centred from egocentric neglect because in many tasks egocentric and stimulus-centred coordinates are overlapping, for example when the egocentric reference frame is retinotopic and the fixation of stimuli is central. Therefore there is still a controversy about the stimulus-centred frame of reference. Some authors suggest, that purely egocentric representation of space might account for phenomena that seem to be stimulus-centered in origin (Buxbaum, Coslett, Montgomery, & Farah, 1996; Driver & Pouget, 2000; Niemeier & Karnath, 2002).

Most clinical investigations focused on egocentric (that is viewer-centered) neglect, providing abundant evidence that information is neglected depending on its position relative to body coordinates, e.g. to the retina (Hillis, Rapp, Benzing, & Caramazza, 1998) or trunk (Beschlin, Cubelli, Della Sala, & Spinazzola, 1997; Chokron, 2003; Farah, Brunn, Wong, Wallace, & Carpenter, 1990; Farne, Ponti, & Làdavvas, 1998; Karnath, 1997; Mennemeier, Chatterjee, & Heilman, 1994). In the assessment of egocentric visuospatial behaviour after brain damage, visual search paradigms are widely used – particularly since visual search may involve processes with low (parallel feature search) or else high demands on visual attention (Chelazzi, 1999; serial conjunction search; for review see Wolfe & Horowitz, 2004). A recent study of a large patient group focussed on response slopes in parallel and serial search displays with increasing numbers of distractors (Behrmann, Ebert, & Black, 2004). The authors found generally impaired search in brain damaged patients for contralesional targets in both parallel feature and serial conjunction search compared to healthy controls. This impairment was stronger in patients with additional neglect and/or hemianopia.

In the majority of cases associations between egocentric and allocentric frames of reference have been reported. Patients may show viewer-centered or else stimulus-centered neglect depending on task instruction (Baylis, Baylis, & Gore, 2004), and both forms of neglect can occur in the same patient (Laeng,

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