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Representation and disconnection in imaginal neglect☆

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ABSTRACT

Patients with neglect failure to detect, orient, or respond to stimuli from a spatially confined region, usually on their left side. Often, the presence of perceptual input increases left omissions, while sensory deprivation decreases them, possibly by removing attention-catching right-sided stimuli (Bartolomeo, 2007). However, such an influence of visual deprivation on representational neglect was not observed in patients while they were imagining a map of France (Rode et al., 2007). Therefore, these patients with imaginal neglect either failed to generate the left side of mental images (Bisiach & Luzzatti, 1978), or suffered from a co-occurrence of deficits in automatic (bottom-up) and voluntary (top-down) orienting of attention. However, in Rode et al.'s experiment visual input was not directly relevant to the task; moreover, distraction from visual input might primarily manifest itself when representation guides somatomotor actions, beyond those involved in the generation and mental exploration of an internal map (Thomas, 1999). To explore these possibilities, we asked a patient with right hemisphere damage, R.D., to explore visual and imagined versions of a map of France in three conditions: (1) 'imagine the map in your mind' (imaginal); (2) 'describe a real map' (visual); and (3) 'list the names of French towns' (propositional). For the imaginal and visual conditions, verbal and manual pointing responses were collected; the task was also given before and after mental rotation of the map by 180°. R.D. mentioned more towns on the right side of the map in the imaginal and visual conditions, but showed no representational deficit in the propositional condition. The rightward inner exploration bias in the imaginal and visual conditions was similar in magnitude and was not influenced by mental rotation or response type (verbal responses or manual pointing to locations on a map), thus suggesting that the representational deficit was robust and independent of perceptual input in R.D. Structural and diffusion MRI demonstrated damage to several white matter tracts in the right hemisphere and to the splenium of corpus callosum. A second right-brain damaged patient (P.P.), who showed signs of visual but not imaginal neglect, had damage to the same intra-hemispheric tracts, but the callosal connections were spared. Imaginal neglect in R.D. may result from fronto-parietal dysfunction impairing orientation towards left-sided items and posterior callosal disconnection preventing the symmetrical processing of spatial information from long-term memory.

Introduction

Patients with right hemisphere damage and left visual neglect are sometimes unable to describe the left part of internally generated images. This representational, or imaginal, neglect has been ascribed to a failure to generate or maintain a normal representation of the contralesional side of mental images (Berti, 2004; Bisiach & Berti, 1987; Bisiach & Luzzatti, 1978; Bisiach, Luzzatti, & Perani, 1979). Representational neglect is commonly assessed by requiring subjects to draw objects from memory (Chokron, Colliot, & Bartolomeo, 2004; Critchley, 1953) or to name the towns or the countries on an imagined map (Bartolomeo, D'Erme, & Gainotti, 1994; Rode & Perenin, 1994).

The presence or absence of visual input may influence neglect patients' performance in drawing from memory. Perceptual input increases left omissions, while the absence of visual feedback may decrease them. For example, Anderson (1993) reported on a patient with neglect who displayed an object-centered neglect with the eyes open, which disappeared with the eyes closed. Chokron et al. (2004) described a similar pattern of performance in 3 out of

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6 right-brain damaged patients with neglect. In the same study, 5 patients also showed improved drawing symmetry when blindfolded, reflecting an increase in the extent and the number of details on the left side of the drawing and a reduction of the extent of the right. These results suggest that the attentional capture exerted by the right-sided details of drawings that subjects were producing may be reduced in the absence of visual input, thus facilitating a leftward orienting of attention (Bartolomeo, 2007).

Does visual input exert a similar influence on representational neglect when assessed by description from memory? Such a possibility might suggest that similar attentional systems are impaired in perceptual and in imaginal neglect (Bartolomeo & Chokron, 2002a). However, evidence contrary to this hypothesis emerged from a recent study (Rode, Revol, Rossetti, Boisson, & Bartolomeo, 2007), in which 8 normal participants and 8 brain-damaged patients with left representational neglect were invited to imagine the map of France and to name as many towns as possible within 2 min, either with their eyes open or while blindfolded. Patients' representational neglect remained unchanged by the presence/absence of visual input. The defective retrieval and generation from long-term memory of topographic information about towns on the western part of the map was the same in both conditions, while performance on mental evocation of towns on the middle and eastern parts of the map was similar in both conditions and not different from healthy controls. These findings suggested that visual input did not influence the mental representation of space in a task requiring only visual mental imagery (Rode et al., 2007), and that such representational deficit may result from either a failure to generate the left side of mental images (Bisiach & Luzzatti, 1978), or the co-occurrence of distinct deficits in orienting of attention, perhaps involving automatic (bottom-up) and voluntary (top-down) orienting (Bartolomeo et al., 1994).

However, it must be noted that visual input was not relevant in the map description task used in this study, in contrast to visual feedback in the drawing task, where the already drawn details were obviously important to the progression of the task. Task-relevant visual details might be more effective in capturing patients' attention (Ptak & Schnider, 2006). Also, visual input might influence performance on spatial representation tasks only when these tasks require a manual response, i.e. an interaction between neural processes supporting visual representation and action. Even without visual input, such tasks incorporate a major intentional component that underlies the act of drawing itself as well as the ongoing dynamic process involved in repeatedly comparing what is imagined to have been drawn with the original mental image template. This intentional component could also help patients with imaginal neglect to obtain more symmetrical levels of performance (Cristinzio et al., 2009).

In order to explore these issues, we asked a patient with right hemisphere damage and signs of robust left representational neglect to recall topographic knowledge about towns of France in different conditions: when imaging the map of France, when viewing a map presented in front of him and without any imaginal or perceptual requirements. Moreover, for imagery and perceptual conditions, two types of answer were noted (verbal and motor) and tasks were also applied before and after a mental rotation of the map by 180°.

A further important issue concerns the lesional correlates of imaginal neglect. There is currently an intense debate about the anatomy of perceptual neglect, whose typical lesional correlates were classically identified with the inferior parietal gyrus (Mort et al., 2003; Vallar, 2001) or, more recently, with the central/rostral portions of the superior temporal gyrus (Karnath, Ferber, & Himmelbach, 2001). Other results stress the importance of white matter disconnections (Bartolomeo, Thiebaut de Schotten, & Doricchi, 2007), especially in the fronto-parietal components of the superior longitudinal fasciculus (SLF) (Thiebaut de Schotten et al., 2005). Fronto-parietal networks are important for spatial orienting and other attentional processes. Dysfunction of these networks in neglect is broadly consistent with the prominent attentional problems in these patients. In a similar way, the study of the lesional correlates of imaginal neglect can provide evidence relevant to its functional mechanisms. Imaginal neglect has not been thoroughly explored in this respect. Many cases have large right-hemisphere lesions similar to those observed in patients with perceptual neglect (Bartolomeo et al., 1994; Bisiach, Capitani, Luzzatti, & Perani, 1981). Single cases with isolated imaginal neglect had lesions in the dorsolateral prefrontal cortex (Guariglia, Padovani, Pantano, & Pizzamiglio, 1993) or the thalamus (Ortigue et al., 2001). However, anatomical studies on imaginal neglect did not address the possibility that disconnection factors may contribute to this deficit. For the present patient, high-definition anatomical MRI was obtained, as well as diffusion sequences employed for subsequent DTI-based reconstruction of relevant white matter tracts. Neuroimaging results were compared with those of a second right-brain damaged patient, who had signs of visual neglect in the absence of representational impairment.

Patients

Two right-handed patients with unilateral lesions in the right hemisphere participated in the study after having signed a written informed consent form.

Patient R.D., a 75-year-old man, with 10 years of schooling, who had been working as a craftsman, was admitted to a neurological unit for the sudden onset of left-sided weakness, confusion, left homonymous hemianopia, and left spatial neglect, consecutive to a vascular infarct in the territory of the right middle cerebral artery. This stroke was secondary to a thrombosis of the right internal carotid artery due to cardiac embolism in a context of cardiac arrhythmia. One month after stroke onset, the patient showed a mild left upper limb paresis with somatosensory and proprioceptive deficits. Goldmann's perimetry demonstrated a left homonymous hemianopia. Visual acuity was corrected-to-normal (10/10) with lenses for the two eyes. The patient also showed left auditory and somatosensory extinction to double simultaneous stimulation. Neither motor neglect nor motor extinction was present.

Neuropsychological examination one month post-onset revealed a persistent left-sided neglect. On the Bell's cancellation task (Gauthier, Dehaut, & Joanette, 1989), the patient crossed out 23/35 targets, with 11 omissions on the left half of the sheet and one omission on the right half. In a letter cancellation task (Diller & Weinberg, 1977), the patient crossed out 8/25 targets on the left half, and 24/25 targets on the right half of the sheet. On a line bisection task (Schenkenberg, Bradford, & Ajax, 1980), the patient displaced the subjective center rightwards by 31% of the total line length on average. The patient showed evidence of object-centered neglect in a drawing copy task (Gainotti et al., 1972), with left-sided omissions of 3 items. He also omitted left-sided items when asked to complete a clock-face from memory, or to draw or copy a daisy or a tree. The patient also had signs of constructional apraxia when drawing figures such as a cube or a house. Verbal description from memory of objects or animals was flawless. There was no impairment on verbal fluency tasks: Patient R.D. gave respectively 17, 14 and 10 correct responses for the letters /P/, /R/and /V/ in a verbal fluency alphabetic test (normal values: 19.28 ± 7.05 for /P/; 16.78 ± 6.04 for /R/ and 14.5 ± 6.46 for /V/) and 23, 12 and 10 correct responses for the items /animal/, /fruit/ and /furniture/ in a verbal fluency categorical test (normal values: 27.14 ± 8.53 for /animals/; 15.42 ± 3.85 for /fruits/ and 11.71 ± 3.53 for/furniture/) within 2 min (Cardebat, Doyon, Puel, Goulet, & Joanette, 1990).