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Visuospatial neglect in near and far space: dissociation between line bisection and letter cancellation

I. Keller[a,*], I. Schindler[b], G. Kerkhoff[c], F. von Rosen[a], D. Golz[d]

[a] *Neurological Clinic Bad Aibling, Kolbermoorer Strasse 72, 83043 Bad Aibling, Germany*
[b] *Cognitive Neuroscience Research Unit, Wolfson Research Institute, University of Durham, England*
[c] *EKN-Clinical Neuropsychology Research Group, Hospital Bogenhausen, Munich, Germany*
[d] *Institute of Psychology Friedrich-Wilhelm-University Bonn, Germany*

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Abstract

The differential performance on a line bisection and a cancellation task in near and far space was studied. A group of 10 patients with severe left-sided visuospatial neglect and a group of 10 right-brain damaged patients without neglect were examined. The stimuli were presented at a distance of 60 cm (near space) and 160 cm (far space), respectively, and corrected for visual angle. In the line bisection task, patients were asked to point to the estimated line centre with a pencil (near space) or a stick (far space). In the cancellation task, patients pointed to all target stimuli they could detect using either a pencil (near space) or a stick (far space).

Most patients with left hemineglect showed a more prominent neglect in far space as compared to near space for the line bisection task, whereas no difference of performance between near and far space was found in the control patients. In contrast, no group showed a distance effect in the cancellation task.

The observation that only line bisection is influenced by the distance of the stimulus suggests that line bisection and cancellation are processed differentially. It is proposed that line bisection requires an allocentric reference system focusing attention on objects, whereas cancellation tasks are based on an egocentric reference system responsible for visuospatial attention. Our results indicate that distance changes perception within the allocentric but not within the egocentric system.

Keywords: Right-brain damage; Visuospatial neglect; Distance; Line bisection; Cancellation

1. Introduction

Unilateral neglect is a cluster of symptoms characterized by a failure to orient, or react to stimuli located predominantly on the contralesional side (Heilman, Valenstein, & Watson, 1985). One of several dissociations of the neglect syndrome consists in a differential degree of severity of the visuospatial deficit in near and far space (Berti & Frassinetti, 2000; Cowey, Small, & Ellis, 1994, 1999; Halligan & Marshall, 1991; Pitzalis, Russo, Spinelli & Zoccoletti, 2001; Vuilleumier, Valenza, Mayer, Reverdin & Landis, 1998; for a detailed review see Berti & Rizzolatti, 2002). There is evidence from neurophysiological studies that activation of different motor systems for near and far space might be responsible for this dissociation. Roland, Skinhøj, Lassen and Larsen (1980) found an increase in regional cerebral blood flow (rCBF), in the supplementary motor area and contralateral primary motor area which was restricted to motor activity towards visual stimuli in near space. On the contrary, responses to stimuli in far space were associated with bilateral activation of the superior and inferior parietal regions (Roland et al., 1980). Recently, Weiss et al. (2000) used PET to determine which brain regions are implicated when normal volunteers bisect horizontal lines and point to dots in peripersonal or extrapersonal space. They found that attending to and acting

* Corresponding author. Tel.: +49 8061 903 560; fax: +49 8061 903 9560.
E-mail address: IKeller@Schoen-Kliniken.de (I. Keller).

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in near space activated the left dorsal occipital cortex, left intraparietal cortex, left ventral premotor cortex and left thalamus, whereas attending to and acting in far space involved the ventral occipital cortex bilaterally and the right medial cortex.

Further support for a separation of near and far space in the brain comes from animal studies. Neurons in frontal area 6 and in the rostral part of the inferior parietal lobe of the monkey (Leinonen, Hyvarinen, Nymani & Linnankoski, 1979), as well as neurons in area VIP (Duhamel, Bremmer, BenHamed, & Graf, 1997), respond predominantly to stimuli in near space. Additionally, Rizzolatti, Matelli and Pavesi (1983) demonstrated that monkeys with lesions in these areas did not attend to stimuli located near the body, whereas they were able to detect stimuli in far space. On the other hand, ablation of the frontal eye field of the monkey results in an attentional deficit for stimuli presented contralateral to the brain lesion especially for stimuli in far space (Latto & Cowey, 1971).

Neuropsychological studies with neglect patients indicate that right-sided brain lesions can lead to a neglect-like visuospatial deficit, which is either more related to near space or to far space. Two single case studies by Halligan and Marshall (1991) and Berti and Frassinetti (2000) described patients after right hemisphere stroke with marked left visual neglect on a line bisection task in near space that was reduced when the line was presented in far space. In addition, Berti and Frassinetti demonstrated that this dissociation in performance can disappear when line bisection is performed with a stick instead of a light pen. The authors interpreted this effect within an evolutionary theory, proposing that using a tool in order to reach an object in far space causes a remapping of space (far is remapped as near). Besides these reports, there are also studies showing the opposite dissociation. Cowey et al. (1994) investigated line bisection in five neglect patients. All patients misplaced the centre of the line to the right in near and far space. However, most patients showed a significantly bigger angular displacement in far space than in near space for lines of identical angular size. In a second study, Cowey et al. (1999) replicated these results. In five out of 13 patients the bisection error was more pronounced for lines beyond than for lines within reaching distance. They also observed no sudden increase in the angular displacement when the maximum reaching distance was exceeded. Using PET in healthy volunteers, Weiss, Marshall, Zilles and Fink (2003) recently compared brain activity for visuo-manual and purely perceptual versions of a line bisection paradigm in near and far space, respectively. They found evidence for a dorsal stream involvement in the manual condition and in near space and a ventral stream activation for the verbal and far space condition. Interestingly, the neural activations associated with the two tasks were not differentially modulated by distance.

In summary, evidence from neurophysiological research suggests that stimuli presented in near and far space are processed within different brain regions, respectively. The experiments in neglect patients primarily looked for distance effects on the line bisection task. So far, only Vuilleumier et al. (1998) presented a patient suffering from a right-sided haematoma who showed a marked left visual neglect for far space but not for near space in a variety of tasks such as reading, letter cancellation and line bisection. In contrast, Pizzamiglio et al. (1989) failed to find a clear difference between performance in near and far space. They used a modified version of the Wundt–Jastrow area illusion test, a task which requires no motor response. The performances of neglect patients at two different distances were highly correlated, suggesting that distance related behavioural dissociations depend on the presence or absence of a motor response. Nevertheless, it seems plausible that different cognitive aspects of tasks are related to activations of different brain systems. For instance, Fink et al. (2000) using functional imaging showed that line centre judgements activated the right parietal cortex, whereas square-centre judgements activated the lingual gyrus bilaterally. These results suggest that different visual stimulus configurations evoke a different functional anatomy related to the performance of the specific spatial task. Thus, it seems plausible that similar distinct neural circuits might also exist for line bisection and cancellation tasks. This idea is supported by the findings of a small group study in right-hemisphere damaged patients assessing the degree of impairment in a traditional cancellation and line bisection paradigm (Halligan & Marshall, 1992). The authors observed a reliable double dissociation between both tasks in two out of four patients. In another lesion study, in 21 unselected neglect patients Binder, Marshall, Lazar, Benjamin and Mohr (1992) showed that patients with lesions in the right temporo-parieto-occipital area are frequently impaired in cancellation as well as line bisection. In contrast, the maximal lesion overlap in patients who were *only* impaired in cancellation was found in pre-rolandic regions including the prefrontal cortex, insula and adjacent subcortical areas.

Halligan and Marshall (1992) proposed that the displacement of the midpoint is not a result of neglecting a portion of the left. Rather, patients judge that two unequal magnitudes are the same, just as do normal subjects albeit with lesser inequalities. For cancellation tasks, Weintraub and Mesulam (1988) have shown that stimulus content and spatial array modulate neglect supporting the hypothesis that a lack of systematic visual exploration within extrapersonal space is one factor associated visual hemispatial inattention. In this context, De Renzi, Gentilini, Faglioni and Barbieri (1989) showed the requirements of visual search tasks seem to be primarily sensitive to a shift of visuospatial attention. On a functional level it might be hypothesized that line bisection requires the patient to focus attention on the horizontal extent of *one single* specific object (the line). On the other hand, cancellation tasks, in which neglect patients typically fail to detect target stimuli on the contralesional, left side, require the patient to scan randomly structured *multiple* object arrays (e.g. digits, letters or symbols). Attention in cancellation tasks is, therefore, more related to visuospatial exploration of different, successive locations on the display.