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Near and far space neglect: Task sensitivity and anatomical substrates

Lina Aimola[a], Igor Schindler[b,*], Anna Maria Simone[c], Annalena Venneri[d,e]

[a] Cognitive Neuroscience Research Unit, University of Durham, UK
[b] Clinical Neuroscience Centre, University of Hull, UK
[c] University of Modena and Reggio Emilia, Italy
[d] Department of Neuroscience, University of Sheffield and Sheffield Teaching Hospital NHS Foundation Trust, Sheffield, UK
[e] San Camillo Research Hospital, IRCCS, Venice, Italy

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ABSTRACT

Most group studies which have investigated neglect for near and far space have found an increased severity of symptoms in far space compared to near space. However, the majority of these studies used relatively small samples and based their findings almost exclusively on line bisection performance.

The aim of the present study was, therefore, to explore the occurrence of neglect for near and far space in a larger group of unselected right brain damaged patients and to evaluate whether neglect specific to near and far space is a task-related deficit or generalises across distance irrespective of task. In addition, a lesion overlap analysis was carried out to identify critical lesion sites associated with distance specific neglect deficits.

Thirty-eight right hemisphere damaged patients carried out a line bisection and a cancellation task by using a pen in near space (40 cm) and a laser pointer in far space (320 cm).

The results showed that both the number of left-sided omissions and rightward bisection errors were significantly increased in near compared to far space. Distance specific dissociations, albeit less common, were more frequently observed for cancellation than line bisection.

These results suggest that space representation in neglect is more severely impaired in near than in far space. In addition, distance related dissociations in neglect may depend on task demands. Although the anatomical findings were broadly consistent with a dorsal and ventral stream dichotomy for near and far space processing, they also suggest the involvement of intermediate structures in distance related neglect phenomena.

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1. Introduction

Patients with neglect show lack of awareness for events and items located on the contralesional side of space (Halligan & Marshall, 1993; Heilman & Van Den Abell, 1980). The clinical manifestations of this syndrome and their anatomical correlates are heterogenous and may vary along a wide range of different domains such as input/output dimensions, sensory modality, spatial reference frames and sectors of space (Kerkhoff, 2001; Vallar, Bottini, & Paulesu, 2003). It has been argued, therefore, that the conflicting results of group studies which have identified either damage in the right angular gyrus (Mort et al., 2003) or in the right superior temporal gyrus (Karnath, Berger, Kuker, & Rorden, 2004; Karnath, Rennig, Johannsen, & Rorden, 2011) as the main determinants of neglect might have been biased by heterogeneity of samples including different proportions of neglect subtypes (Hillis et al., 2005). This suggestion seems to be supported by a recent study which used voxel based lesion mapping (VSLM) and found specific associations between lesions in the inferior parietal lobe, dorsolateral prefrontal cortex and temporal lobe and perceptual, visuomotor and object-centred neglect respectively (Verdon, Schwartz, Lovblad, Hauert, & Vuilleumier, 2010). Studies that have specifically investigated the neuroanatomical correlates of neglect related to spatial reference frames found that egocentric (viewer-based) neglect was associated with hypoperfusion and damage in the right dorsal stream (premotor cortex, right angular- and supramarginal gyrus) and allocentric (object-based) neglect with abnormal perfusion in more ventral areas (inferior temporal gyrus, superior temporal cortex (Grimsen, Hildebrandt, & Fahle, 2008; Hillis et al., 2005). Structural damage to the interparietal sulcus and temporo-parietal cortex, on the other hand, seem to be related to both forms of neglect (Chechlacz et al., 2010).

However spatial neglect manifestations can not only dissociate along the egocentric/allocentric dimension but also depending on whether tasks are performed in near space (within reaching distance) or far space (beyond reaching distance) (Halligan, Fink, Marshall, & Vallar, 2003). Given that neglect is typically assessed

* Corresponding author at: Department of Psychology, University of Hull, Cottingham Road, Hull HU6 7RX, UK. Tel.: +44 1482 465563; fax: +44 1482 465599.
E-mail address: i.schindler@hull.ac.uk (I. Schindler).

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in near space it is currently unclear whether neglect specific to one sector is a common phenomenon and what the possible underlying anatomical substrates of such dissociations are.

Most of our current knowledge of distance effects on the phenomenology of neglect comes from single case studies (Barrett, Schwartz, Crucian, Kim, & Heilman, 2000; Berti & Frassinetti, 2000; Berti, Smania, & Allport, 2001; Halligan & Marshall, 1991; Mennemeier, Wertman, & Heilman, 1992; Shelton, Bowers, & Heilman, 1990; Vuilleumier, Valenza, Mayer, Reverdin, & Landis, 1998).

To date, the group studies that have reported a significant modulatory effect of distance on neglect severity assessed relatively small patient samples (Butler, Eskes, & Vandorpe, 2004; Cowey, Small, & Ellis, 1994, 1999; Keller, Schindler, Kerkhoff, von Rosen, & Golz, 2005; Pitzalis, Di Russo, Spinelli, & Zoccolotti, 2001). Cowey et al. (1994), for example, found a significantly larger rightward bisection error in far space compared with near space in a group of five patients with neglect. A similar pattern of more severe impairment in far than in near space was also observed by other studies that investigated larger samples of neglect patients to explore distance related deficits with line bisection paradigms (Cowey et al., 1994, 1999; Pitzalis et al., 2001) or, in one case, with a cancellation task (Butler et al., 2004). Some studies, however, were unable to observe any difference between neglect severity in near and far space at a group level, except for distance related dissociations in individual cases of neglect in line bisection and on the Wundt-Jastrow area illusion test (Neppi-Modona et al., 2007; Pizzamiglio et al., 1989).

Overall, the findings of these studies suggest that neglect appears to be more severe in far than in near space (Butler et al., 2004; Cowey et al., 1994, 1999; Keller et al., 2005; Pitzalis et al., 2001).

However, most of these group studies were based on line bisection paradigms while very little is known about the effect of distance on neglect in cancellation tasks. Line bisection and cancellation tasks are both classic methods for the assessment of spatial neglect in clinical settings. These tasks, however, seem to engage very different visuospatial operations: cancellation tasks require the exploration of randomly structured multiple object arrays whereas line bisection judgements require one to focus attention on the horizontal extent of one single specific object. It has been demonstrated, however, that neglect-related performance in these tasks can dissociate, and correlates poorly, and it has also been shown that poor performance on these tasks may result from damage to different brain structures (Binder, Marshall, Lazar, Benjamin, & Mohr, 1992; Ferber & Karnath, 2001; McGlinchey-Berroth et al., 1996; Rorden, Berger, & Karnath, 2006). For example, lesion group studies that classified neglect based on a battery of visual exploration tasks found maximal lesion overlap in the superior temporal gyrus and insula (Karnath, Ferber, & Himmelbach, 2001; Karnath et al., 2004), whereas studies that defined neglect based on performance pooled across line bisection and cancellation identified maximal lesion overlap in the angular gyrus and temporo parietal junction (TPJ) (Mort et al., 2003). A recent study by Rorden et al. (2006) addressed this issue by comparing neglect patients with line bisection deficits with those without neglect on this task and found that impairments in line bisection were strongly associated with damage to the TPJ.

This finding seems to suggest that line bisection or perceptual size judgments involve more posterior brain regions, while visual exploration abilities appear to be more frequently associated with lesions of more anterior areas.

Butler et al. (2004) explored the sensitivity of cancellation tasks in detecting visual search deficits in neglect patients across near and far space. This study found a lateral gradient of target detection with more omissions on the left than on the right which was significantly increased in far-compared with near space (Butler et al., 2004). As the authors did not include a line bisection paradigm in their study, it was not possible to verify whether a similar pattern of neglect impairment related to spatial distance would occur independently of the task. Keller et al. (2005) have published the only group study in which distance specific deficits in neglect patients were investigated with both line bisection and cancellation tasks. Although rightward bisection errors were found to increase significantly with distance, no dissociation between near and far space was observed in the cancellation task.

Taken together, these studies suggest that at the group level, neglect seems to be generally more severe in far than in near space. In addition, visual exploration abilities appear less susceptible to modulation by spatial distance than line length judgments. In other words, distance appears to alter bisection judgements but not visual exploration abilities during search for multiple targets in an array. Moreover, the clinical dissociations observed in individual patients suggest the presence of distinct neuronal modules underlying specific cognitive operations for the coding of near and far space. Some limited evidence for this comes from an anatomical group study that found deficits in extrapersonal space was related to damage in the right frontal and superior temporal cortex whereas personal (body) neglect was associated with lesions in the inferior parietal cortex (Committeri et al., 2007). However, it needs to be pointed out that this study did not assess performance beyond reaching distance.

Interestingly Previc (1990, 1998) suggested that the neuronal substrates supporting the representation of near and far space may broadly map onto the dorsal and ventral high visual pathways. Based on research into the processing of three-dimensional visual space in the primate brain, Previc argued that the lower and upper visual fields are biased towards peripersonal (near) and extrapersonal (far) space respectively. This distinction is based on findings showing a lower field advantage in global form and motion processing or pursuit eye movements. An upper field bias has been reported for visual object memory and imagery as well as for visual search. This relative dichotomy seems to be supported by a stronger anatomical segregation of the magnocellular pathways and parvocellular pathways mapping onto the ventral and dorsal stream respectively in primates compared with other mammals. Thus, Previc suggests a dorsal stream/lower visual field bias for manual, goal-directed actions which are generally performed in near space. In contrast, he assumes a ventral stream/upper visual field advantage for extrapersonal, retinotopic space for visual operations carried out beyond reaching distance such as object identification, visual search and scene perception.

The present study investigated the frequency and the consistency of these behavioural patterns by using a larger scale group study approach. More specifically, the first aim was to explore the occurrence of neglect for near and far space in a larger group of unselected right brain damaged patients to characterize the predominant space-related behavioural deficits within this patient group. Secondly, the extent to which distance related neglect can be affected by the cognitive demand of task was also investigated by directly comparing the performance in cancellation and line bisection tasks across near and far space in the same group of right brain damaged patients. Thirdly, to clarify whether there are any anatomical differences between those patients showing neglect restricted to near space or far space only, an exploratory lesion analysis was carried out on the patients' brain scans.

2. Methods

2.1. Participants

A group of 38 unselected right hemisphere damaged patients (M = 25, F = 13; mean age = 65 years, SD = 12.12, mean education = 7.58 years, SD = 3.34) was recruited from the Neurology Clinic of the Nuovo Ospedale Civile S. Agostino

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