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Research Report

Disturbed line bisection is associated with posterior brain lesions

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ARTICLE INFO

Article history:
Accepted 27 October 2004
Available online 7 March 2006

Keywords:
Attention
Neglect
Temporal lobe
Parietal lobe
Brain-damage
Human

ABSTRACT

Neglect patients classically fail to orient and respond to stimuli appearing on their contralesional side. Traditionally, the neglect syndrome has been associated with damage to the right inferior parietal lobule (IPL) and the right temporo-parietal junction (TPJ). Neglect is popularly assessed by two different tasks: line bisection and cancellation. In a previous study (S. Ferber, H.-O. Karnath, How to assess spatial neglect-line bisection or cancellation tasks. J. Clin. Exp. Neuropsychol. 23 (2001) 599–607), we observed that performance on the cancellation task correlates well with the characteristic behavioral disorders used to clinically diagnose spatial neglect, while line bisection was a poor predictor. This might indicate that the disability to correctly bisect lines is a distinct disorder separable from spatial neglect. Here, we assess the anatomy of the patients investigated in that study, and reveal that damage to the temporo-occipital junction correlates with poor performance in the line bisection task. This work extends previous work by Binder et al. (J. Binder, R. Marshall, R. Lazar, J. Benjamin, J.P. Mohr, Distinct syndromes of hemineglect. Arch. Neurol. 49 (1992) 1187–1194) suggesting that line bisection and cancellation identify distinct syndromes. The data suggest that these two tasks dissociate both in terms of behavior and anatomy. This anatomical distinction may help reconcile our recent finding that spatial neglect is associated with damage to the superior temporal cortex and insula, while others have identified the IPL and TPJ. Specifically, we note that our previous anatomical studies did not use the line bisection task to select neglect patients, while many others used this task. We suggest that anatomical studies that combine patients from both of these two distinct groups may result in misleading findings.

1. Introduction

Patients suffering from spatial neglect show profound deficits in everyday tasks, spontaneously gazing predominantly to the ipsilesional side, only eating food from the ipsilesional side of their plate and ignoring people located on their contralesional side. This syndrome is of great theoretical interest, as it can help us describe how the intact brain completes spatial tasks. In addition, spatial neglect is of clinical interest, as the presence of neglect is a predictor of impaired long-term functional recovery (for review Karnath and Zihl, 2003). Thus, it is unsurprising that

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0006-8993/$ – see front matter © 2006 Published by Elsevier B.V.
doi:10.1016/j.brainres.2004.10.071

neglect is a heavily researched topic. However, the literature investigating this syndrome has led to a large number of disagreements regarding its nature and anatomical basis. Indeed, some have even despaired that neglect may be a meaningless entity (Halligan and Marshall, 1992).

This skepticism is exemplified by the observation that the two most popular tasks traditionally used to diagnose the syndrome, the line bisection and the cancellation tasks, appear to dissociate from each other. In the line bisection task (Heilman and Valenstein, 1979), the participant is asked to mark the midpoint of a horizontal line. The traditional view is that patients with neglect bisect lines ipsilesionally to the true midpoint (though this pattern reverses with short lines (Halligan and Marshall, 1988)). A second popular task for identifying and quantifying neglect is the cancellation task, where patients are asked to mark a large number of target stimuli in an array of distractors (Gaunthier et al., 1989; Weintraub and Mesulam, 1985). Patients with spatial neglect tend to ignore contralesionally located targets. As both the line bisection and the cancellation tasks are typically used to assess spatial neglect, one would expect performance on these two tests would show a strong correlation with each other. However, there are now many studies that reported apparent dissociations between these two tasks (Binder et al., 1992; Ferber and Karnath, 2001a; Halligan and Marshall, 1992; Halligan et al., 1990; Marshall and Halligan, 1995; McGlinchey-Berroth et al., 1996). Of course, each behavioral test is a noisy measure of underlying deficits, so one might expect occasional dissociations for single subjects. Nevertheless, a series of group studies (Binder et al., 1992; Ferber and Karnath, 2001a; McGlinchey-Berroth et al., 1996) clearly illustrate that these two tasks dissociate. Of particular interest, a recent group study by Ferber and Karnath (2001a) compared how well each of these tasks correlated with the typical clinical behavior associated with spatial neglect, that is, a tendency to spontaneously gaze toward the ipsilesional side, orienting ipsilesionally when addressed from the contralesional side, ignoring people or objects located on the contralesional side, impaired clock drawing, and impaired picture copying. Ferber and Karnath found that performance in the cancellation tasks (especially in the letter cancellation task (Weintraub and Mesulam, 1985) and the bells test (Gaunthier et al., 1989)) corresponded well with the clinical behavior of the patients. On the other hand, their scores in the line bisection task showed very poor correlation with neglect. In fact, 40% of the patients who showed the typical clinical signs for spatial neglect (see above) were unimpaired in the line bisection task. In other words, the performance in line bisecting does not reflect the characteristic behavioral disorders observed in patients with spatial neglect following a right hemisphere stroke.

This observation should not be interpreted as suggesting that poor performance on the line bisection task is not clinically important in its own right: it suggests a profound spatial deficit. One interpretation of this finding is that line bisection is simply a less sensitive task for spatial neglect. On the other hand, line bisection and cancellation make different cognitive demands. It is thus possible that they measure different aspects of performance. In any case, it is worth bearing in mind that performance in the popular line bisection task does not seem to be particularly sensitive to spatial neglect, and may indeed be measuring a very different system than the circuits tapped by the cancellation task.

In this study, we try to determine whether the dissociation between clinical neglect behavior and the behavior in line bisecting might be explained by a different pattern of brain damage. If each of these tasks were linked with a distinct neural substrate, we would gain insight into the different functional roles of the implicated regions.

Indeed, there is a precedent to expect that different types of brain damage might impair performance on these two tasks. Binder et al. (1992) examined 34 patients with right hemisphere stroke. Importantly, they found no significant correlation between performance on the line bisection and cancellation tasks—while some patients showed deficits on each task, performance on one task did not predict performance on the other task. Interestingly, when Binder et al. performed overlay plots of the patients' brain lesions, they observed that neglect patients who exhibited abnormal line bisection tended to have posterior lesions. In contrast, patients who were only impaired on the cancellation task suffered more anterior damage. Further support for this dissociation comes from studies that show that size perception errors for visual objects (lines, rectangles) are correlated with neglect patients who exhibit posterior damage and visual field defects (Barton and Black, 1998; Daini et al., 2002; Doricchi and Angelelli, 1999; Ferber and Karnath, 2001b).

This finding has important implications for the current dispute regarding the neuroanatomical basis for spatial neglect. Traditionally, damage to the right inferior parietal lobule (IPL) and temporo-parietal junction (TPJ) has been considered the best predictor for spatial neglect (Heilman et al., 1983; Mort et al., 2003; Vallar and Perani, 1986). However, four recent anatomical studies have found the center of lesion overlap in the right superior temporal cortex and insula, suggesting that these structures rather than the inferior parietal lobule are the most frequent cortical substrates for spatial neglect in humans (Karnath et al., 2001; Karnath et al., 2003; Karnath et al., 2004a,b).

Two of these studies intentionally excluded patients with separate neurological disorders that can co-occur with neglect, specifically (i) patients with visual field cuts (Karnath et al., 2001) and (ii) patients with visual field cuts or extinction (Karnath et al., 2003), aiming to isolate the anatomical regions involved with the core deficit of spatial neglect (Fig. 1). However, the exclusion of patients may be a problematic experimental strategy that may lead to inadvertent selection biases (Husain and Rorden, 2003). Two further studies thus were based on *unselected* samples comparing consecutively admitted neglect and control patients without excluding subjects for any additional symptoms (Fig. 2). One of these latter studies employed a technique where the location of the lesion was drawn directly on the patient's own magnetic resonance imaging (MRI) scan using SPM normalization and cost-function masking for subsequent transformation into stereotaxic