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Research report

Impaired search for orientation but not color in hemi-spatial neglect

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ABSTRACT

Patients with hemi-spatial neglect have trouble finding targets defined by a conjunction of visual features. The problem is widely believed to stem from a high-level deficit in attentional deployment, which in turn has led to disagreement over whether the detection of basic features is also disrupted. If one assumes that the detection of salient visual features can be based on the output of spared 'preattentive' processes (Treisman and Gelade, 1980), then feature detection should remain intact. However, if one assumes that all forms of detection require at least a modicum of focused attention (Duncan and Humphreys, 1992), then all forms of search will be disrupted to some degree. Here we measured the detection of feature targets that were defined by either a unique color or orientation. Comparable detection rates were observed in non-neglected space, which indicated that both forms of search placed similar demands on attention. For either of the above accounts to be true, the two targets should therefore be detected with equal efficiency in the neglected field. We found that while the detection rate for color was normal in four of our five patients, all showed an increased reaction time and/or error rate for orientation. This result points to a selective deficit in orientation discrimination, and implies that neglect disrupts specific feature representations. That is, the effects of neglect on visual search are not only attentional but also perceptual.

1. Introduction

Hemi-spatial neglect, or 'neglect' for short, is a relatively common and disabling disorder usually acquired after damage to the right hemisphere (Karnath et al., 2004). The disorder is associated with a variety of clinical symptoms, the most striking of which is a lateralized spatial bias in which patients fail to acknowledge or report information falling on the contralesional side of space. This may lead them to bump into things on the affected side, eat from only one side of their plate or ignore words on one side of a page when reading. In its most extreme form, the bias may even induce ipsilesional rotation of gaze and trunk. The extent to which the symptoms of neglect can be attributed to attentional as opposed to perceptual impairment remains a matter of debate, and is the focus of the current study.

The idea that neglect involves some kind of attentional dysfunction is based on several observations: (1) neglect can occur in the absence of primary motor or sensory loss, (2) the severity of neglect does not correlate with any field cut,

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(3) it cannot be eliminated by replacing a motor response with a verbal one, (4) it can be overcome by prompting a patient towards their neglected field by either a salient exogenous cue or verbal command, and (5) patients with more mild symptoms may show good detection of contralesional stimuli in the absence of ipsilesional competition, indicating that basic sensory encoding and orienting are intact. Beyond this first approximation, however, controversy reigns over the precise nature of impairment.

Some insights have been gained from the study of visual search behavior. In a conventional search task, participants are asked to report the presence/absence of a pre-defined target amongst distractor items. By measuring the effects of distractor number on the speed and accuracy of target detection, one can compare, albeit imperfectly, the attentional cost associated with finding different kinds of target. In healthy controls, search for targets defined by a conjunction of features, such as a red X amongst green Xs and red Os, is slowed by at least 30 msec for every extra distractor that is added (e.g., Treisman and Gelade, 1980). This has been taken to indicate an effortful mode of search in which attention is moved serially from one location to another until the target is found (Wolfe, 1994). Simpler targets such as those defined by a unique feature can be found in a relatively effortless manner and typically generate very small set size effects (<5 msec per item).

The interpretation of these search patterns falls into two camps. Some have argued that the large differences between feature and conjunction search reflect the operation of two qualitatively distinct processing stages; an initial 'preattentive' stage in which basic visual features are recovered in a spatially parallel manner, followed by a second 'attentional' stage in which features are spatially bound into coherent objects under the serial spotlight of attention (Wolfe, 1994). According to this account, if neglect is an attentional disorder then features that can be detected under little or no attention should remain detectable in the neglected field. In support of this, a study conducted in our laboratory found that 'effortless' search for a Q amongst Os produced negligible slopes in patients and controls alike (<9 msec per item), while 'effortful' search for an O amongst Qs tended to produce slopes in left visual field (LVF) that were twice as steep as those seen in healthy, age-matched controls (Esterman et al., 2000). A similar result was reported by Riddoch and Humphreys (1987) who had patients search for either an inverted T amongst heterogeneously oriented Ts or a red circle among green circles. While strong set size effects were observed for the T stimuli, none of the patients showed significant linear effects in either their error or reaction time (RT) data for the simpler color search. This led the authors to suggest that "patients can manifest parallel processing of stimuli on the neglected side of space" (pp. 166–167).

Other models of visual attention make different predictions about search behavior in neglect. According to Biased Competition Theory (Desimone and Duncan, 1995; Duncan and Humphreys, 1992), there is no qualitative distinction between any form of search. Rather, search efficiency falls along a continuum and is determined by both target–distractor and inter-distractor similarity. A key premise is that all forms of search are deemed to require at least some attention (see also Joseph et al., 1997). If one accepts that neglect is at least partly an attentional disorder then it follows that all forms of search will be disrupted to some degree. In support of this, and contrary to the study conducted in our laboratory, two separate studies have shown that patients have difficulty finding a Q amongst Os (Behrmann et al., 2004; Eglin et al., 1994). The findings of Behrmann et al. (2004) are especially persuasive because a relatively large sample size (26 patients) was used, and the experiment was designed in such a way that the potential effects of visual field loss and more general right hemisphere damage could be discounted. Two additional studies indicate that the basic encoding of color and orientation may also be compromised. Contrary to Riddoch and Humphreys (1987), Eglin et al. (1989) found that search for a left-sided red dot among yellow and blue distractors was three times as slow for patients compared to healthy controls. In another study, Pavlovskaya et al. (2002) asked three patients to report the presence/absence of a 45° oriented bar amongst a field of vertical distractors. Unlike the healthy controls, patients found targets increasingly hard to find at more leftward locations.

In sum, it would appear that neglect can interfere with the detection of salient visual features, although the findings from both our laboratory (Esterman et al., 2000) and Riddoch and Humphreys (1987) suggest that this is not inevitable. Taken together, these studies raise an interesting question about the nature of impairment in neglect. While the particulars of any one account differ, the standard view maintains that neglect stems from a failure to orient attention into the contralesional hemispace (see Heilman et al., 1985; Kinsbourne, 1977; Rizzolatti and Berti, 1993). This implies that basic visual processes that place little demand on attention will continue to operate in the neglected field. In the absence of distracting ipsilesional stimuli, it is proposed that these basic processes can signal the presence of very salient stimuli and overcome the spatial bias of neglect. From this standpoint, one can account for instances of impaired feature search by assuming that the explicit detection, but not necessarily the initial encoding, of features requires focused attention.

The purpose of the current study was to further test this attentional hypothesis by comparing patients' abilities to detect qualitatively different visual features. If neglect is solely attentional then the level of impairment should vary as function of the amount of attention needed to find the target. In particular, searches that place a similar demand on attention in non-neglected space should be disrupted to a similar degree in neglected space, regardless of feature type. By contrast, if neglect affects lower, perceptual levels of processing then differences in feature detection should emerge when attentional load is equated. Since no neglect study has yet compared the detection rates of different features within a single group of patients, this hypothesis has yet to be tested.

Here we examined the abilities of five neglect patients to search for targets defined by either a unique color or orientation.[1] In the color experiment, participants searched for a red bar amongst green distractors. In the orientation experiment, they searched for a white, vertical bar amongst white, horizontal distractors in displays that were otherwise

[1] We also report the abilities of a sixth patient, D.E., who through ill-health declined from the study after completing only the orientation task.