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# Modulation of the Directional Attention Deficit in Visual Neglect by Hemispatial Factors[1]

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Using a visuo-spatial cuing paradigm, Posner and collaborators (Posner, Cohen, & Rafal, 1982; Posner, Walker, Friedrich, & Rafal, 1984) reported that subjects with a parietal lobe lesion have difficulty in disengaging their visual attention from an invalidly precued location in the ipsilesional hemifield when the target they have to respond to is presented in the contralesional field. Later, these authors (Posner, Walker, Friedrich, & Rafal, 1987) proposed that this disengagement deficit is one involving spatial shifts of attention in a contralesional direction, irrespective of the visual hemifield in which the target is presented. This proposal of a directional disengagement deficit along the horizontal axis, present in either hemifield, contrasts with a report by Baynes, Holtzman, & Volpe (1986) showing, in right parietal subjects, a disengagement deficit for shifts of attention along the vertical axis that is only manifest in the contralesional hemifield. In the present report, we assessed the disengagement deficit of a neglect subject along the horizontal and vertical axes. Results show a disengagement deficit restricted to shifts of attention in the contralesional direction (horizontal axis), which is significant only in the contralesional visual hemifield. However, there is a clear trend for a directional disengagement deficit in the ipsilateral field. These observations indicate that the attention deficit present in neglect is directional and is modulated either by hemispatial factors or by the lateral target location in the visual field. On the basis of the present results, it is proposed that the deficit of parietal subjects may best be conceptualized as one of attentional capture for stimuli located on the contralesional side of the current focus of attention rather than one of disengagement. 

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## INTRODUCTION

Some individuals with an acquired brain lesion exhibit a conspicuous disorder of visual exploration that cannot solely be explained by sensory impairment such as a visual field defect. This exploration deficit, or visual neglect, can be elicited in many behavioral tasks and is essentially characterized by the subject's failure to notice either the contralesional part of a single stimulus or the most contralesional elements if a number of them are presented. Visual neglect may sometimes be observed in left brain-damaged individuals but is most often seen after right brain lesions (De Renzi, 1982; Gainotti, 1968; Gainotti, Messerli & Tissot, 1972; Hécaen & Angelergues, 1963; Heilman, 1985; Mesulam, 1981; Weinstein & Friedland, 1977). Also, it appears that parietal damage is the most frequent correlate of visual neglect (Bisiach, Luzzatti & Perani, 1979; Critchley, 1953; De Renzi, 1982; Heilman, 1985; Mesulam, 1981; Vallar & Perani, 1986, 1987).

Most of the recent accounts of visual neglect propose that it results from an attentional deficit (Heilman, 1985; Heilman, Bowers, Valenstein, & Watson, 1987; Heilman & Watson, 1977; Kinsbourne, 1970, 1977, 1987; Riddoch & Humphreys, 1983, 1987; Roy, Reuter-Lorenz, Roy, Copland, & Moscovitch, 1987). Accordingly, some authors have undertaken to investigate the functional properties of visual attention in subjects who suffer from damage to parietal regions by using the visuo-spatial cuing paradigm. In this task, the subject is shown in advance the most probable location of a visual target. Typically, valid cues, which indicate the true target location, result in shorter response times (RT's) than cues that are invalid, which signal the wrong location (Eriksen & Hoffman, 1973, 1974; Jonides, 1981; Klein, 1980; Posner, 1980; Posner, Nissen, & Ogden, 1978). The effect of cuing is taken as evidence that the subjects can shift their focus of visual attention toward different spatial locations.

The initial studies, reported by Posner and his collaborators (Posner, Cohen, & Rafal, 1982; Posner, Walker, Friedrich, & Rafal, 1984), made use of a visuo-spatial cuing paradigm in which the target and cue could be presented on either side of a central fixation point. The main discrepancy between the performance of parietal subjects and that of normal controls is that a contralesional target preceded by an invalid cue—that is a cue indicating that the target will be presented in the ipsilesional field—produces abnormally long RT's. This effect was obtained with both left and right parietal subjects, but was particularly large in the latter cases. The results, according to Posner and collaborators, indicate that parietal subjects have a deficit in disengaging their attention from an invalidly cued ipsilesional location when they must focus their attention on a contralesional target.

Given these observations, one question that arises is whether the disengagement deficit found in parietal subjects is specific to targets in the contralesional visual hemifield or whether it occurs only when attention has to be redirected in a contralesional direction, irrespective of the hemifield in which the target is presented. This question is, in fact, closely related to the hypothesized nature of the attentional deficit underlying visual neglect symptoms. Some theories of neglect contend that the disorder is hemispatial in nature, whereas others emphasize the directionality of the syndrome. Thus, according to one view, neglect is the outcome of a failure to attend to the contralesional side of space (Heilman, 1985; Heilman, Walker, Friedrich, & Rafal, 1987; Heilman & Valenstein, 1979; Heilman & Watson, 1977). The alternative hypothesis of a directional deficit maintains that neglect is due to a failure to shift attention toward the most contralesional elements in the visual field (De Renzi, Gentilini, Faglioni, & Barbieri, 1989; Kinsourne, 1970, 1977, 1987; Riddoch & Humphreys, 1983; Roy et al., 1987).

The first experiments reported by Posner and collaborators (Posner et al., 1982, 1984) have not provided a definite answer to this question since the critical variables—the visual hemifield in which the target is presented and the direction of attention shifts after disengagement from the invalidly cued location—were confounded. Moreover, additional experiments (Baynes, Holtzman, & Volpe, 1986; Posner et al., 1987) which attempted to disambiguate these two factors have proven contradictory regarding the nature of the attention deficit in parietal subjects, one outcome suggesting the deficit is hemispatial, another supporting the directionality hypothesis.

Thus, Baynes et al. (1986) found that right parietal subjects exhibited abnormally high RT's to contralesional targets that were preceded by invalid cues indicating a location either *above* or *below* the actual target location (Fig. 1*A*). No such effect was observed with ipsilesional targets. These observations suggest that the attention deficit in right parietal subjects is determined by hemispatial factors (either visual hemifield or corporeal space) since it only occurred with contralesional targets. In addition, these results also suggest that the deficit is not restricted to shifts of attention in a contralesional direction since it was observed for attention shifts along the vertical axis.

In contrast, Posner et al. (1987) found that a target preceded by an invalid cue shown in the same visual hemifield but on its ipsilesional side yields appreciably longer RT's than the same target preceded by an invalid cue shown on its contralesional side (Fig. 1B). Moreover, parietal subjects exhibited this effect for targets in either visual hemifield. These observations suggest that when attention has to be disengaged from an invalidly cued location, the disengagement process takes longer if attention has next to be shifted in a contralesional direction than an ipsilesional one, even for a cue and target that are confined to the ipsilesional hemi-

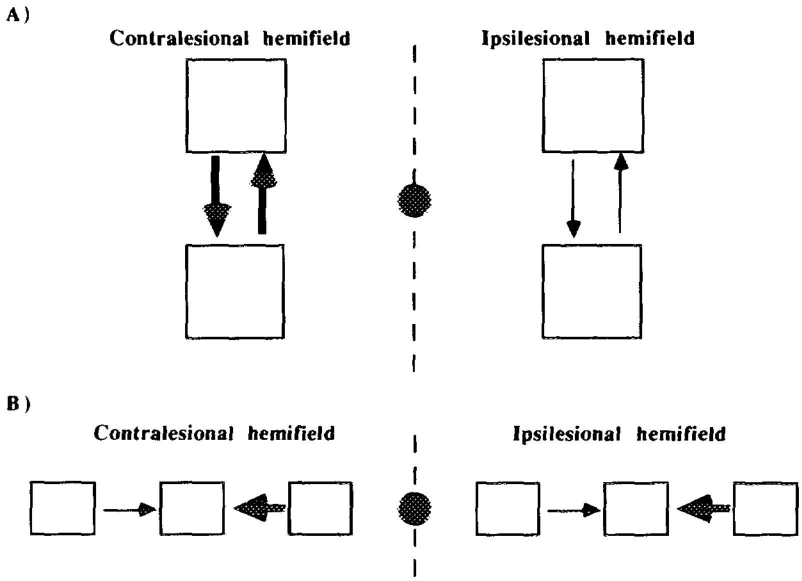


FIG. 1. Features of the attention disengagement impairment in parietal patients. Boxes indicate locations and arrows indicate an attention shift from an invalid cue location to a target location. Thin arrows indicate normal attention shifts and thick arrows indicate impaired attention shifts. (A) Conclusion of Baynes et al. (1986) about the deficit. The impairment is only present for targets in the contralesional hemifield and occurs even if the movement of attention from the cued to the target location follows a vertical axis. (B) Conclusion of Posner et al. (1987) about the deficit. The impairment is present for targets in either visual hemifield and only for attention shifts from the cued to the target location in a contralesional direction.

field. In other words, the experiment of Posner et al. (1987) shows that it is not the target hemifield, but rather the direction of attention shifts which is the critical variable in the deficit of parietal subjects in redirecting their attention from an invalid cue to the target location. An important point to note in the results reported by these authors, however, is that the directional effect interacted with visual hemifield—a smaller disengagement deficit occurred in the ipsilesional hemifield. But Posner et al. (1987) argued that this interaction was due to normally faster attention shifts toward the fovea than toward the visual periphery (Shulman, Wilson, & Sheehy, 1985) and, therefore, that it did not imply any difference across hemifields in the magnitude of the deficit.

The purpose of the research described in this paper is to examine more closely the interactive effects of visual field and directionality on the attention deficit exhibited by parietal subjects. We begin with a more detailed analysis of the results reported by Posner et al. (1987), restricting ourselves to conditions in which no eye movements toward the cued location could occur between the presentation of the spatial cue and that of the target—temporal interval of 100 ms between cue and target. This is to exclude confounds that may result from shifts of ocular fixation. Further, instead of categorizing the direction of disengagement into contralesional and ipsilesional levels as Posner et al. did, we based our division on foveally -directed and peripherally -directed levels. This procedure dissociates the factor of direction and disengagement from that of the normal advantage for shifts of attention toward the fovea relative to shifts toward the periphery.

This new analysis suggests that the impaired disengagement of attention demonstrated by the parietal subjects of Posner and collaborators is, in fact, only present in the *contralesional* hemifield (see Fig. 4; Posner et al., 1987). Thus, RT's are notably longer for contralesional targets than ipsilesional ones when the cue is invalid and the target is located on the *peripheral* side of the cued location. However, the lack of evidence for a comparable disturbance in directional disengagement of attention in the ipsilesional hemifield is reflected by equivalent RT's for contralesional and ipsilesional targets when the cue is invalid and the target is located on the *foveal* side of the cued location. In fact, the direction of the small difference in RT between the relevant conditions is opposite to that predicted by the hypothesis of a directional disengagement deficit. Indeed, evidence supporting a directional disengagement deficit for ipsilesional targets would require that disengagement toward the fovea took longer for ipsilesional targets than contralesional ones, and the results suggest an opposite trend.

We have conducted additional research to reexamine the nature of the attentional disorder in parietal subjects and to establish whether it is determined by hemispatial factors or directionality. Thus far, the evidence reported suggests that the deficit emerges when attention is disengaged from an invalidly cued location and is shifted toward the target location along either a horizontal or a vertical axis. It also suggests that the disengagement deficit is only present for targets shown in contralesional space. The case reported here shows right parietal damage and the task used to assess an attentional disengagement disorder was similar to that used in the previously cited reports (Baynes et al., 1986; Posner et al., 1982, 1984, 1987). Horizontal as well as vertical shifts of attention from an invalidly cued location were tested in conditions that evaluated separately the left and right visual hemifields.

## METHOD

*Subject*. The subject we investigated was a 79-year-old woman with a right parietal lesion of vascular origin. On clinical examination, she showed normal visual fields on confrontation testing, a strong visual neglect, and no visual extinction upon double simultaneous stimulation. Her visual neglect was clearly apparent in a visual search task requiring the selection of multiple occurrences of a target (a small bell shape) drawn on a sheet of paper, presented along with other depicted objects (Gauthier, Dehaut, & Joanette, 1989). Visual extinction upon double simultaneous stimulation was assessed in a task in which either a single stimulus was displayed to the right or left of fixation or two stimuli were presented simultaneously on each side of fixation. Stimulus duration in this task was 100 ms. Tactile extinction was not examined.

*Stimuli.* On each trial, a single target letter (either X or O) was presented in one of eight possible spatial locations on a computer screen, four of them being located on the left of a central fixation point and the four others on the right. Each of these left and right hemispatial locations will be labeled "up," "down," "foveal," and "peripheral." Up and down locations were separated from the central fixation point by a horizontal distance of 5 cm and a vertical distance of 3 cm, the up locations occurring at the top of the display and down locations at the bottom. The foveal and peripheral locations were at the same height as the central fixation point. The foveal locations occurred at a horizontal distance of 2 cm from fixation whereas peripheral locations were situated at a horizontal distance of 8 cm from fixation. The target remained present on the screen until the subject responded. Preceding the presentation of the target by a stimulus onset asynchrony of 200 ms, a visual cue consisting of an empty square centered at one of the possible target locations was displayed for a duration of 150 ms. The subject was seated at approximately 40 cm from the display screen.

*Procedure.* The subject's task was to name the target letter presented on each trial as rapidly and accurately as possible. Verbal RT was the dependent measure. The subject was told that, on most trials, the spatial cue would indicate the correct target location and was instructed to maintain her gaze on the central fixation point as much as possible. Incorrect responses and correct RT's below 150 ms or above 3000 ms were excluded from the data analysis. Only 1.5% of the trials had to be eliminated on the basis of these criteria.

The validity of the spatial cue was 62.5%. On validly cued trials, cue and target were displayed in the same location. When the cue was invalid, the target always occurred in the same hemifield as the cue. With invalid cues in the up or down locations, the target location was aligned vertically with that of the cue (e.g., invalid cue in the up location, target in the down location). With invalid cues in the peripheral or foveal locations, the target was aligned horizontally with the cue (e.g., invalid cue in the peripheral location, target in the foveal location). This stimulus arrangement allows us to evaluate the time required for disengaging attention from an invalidly cued location and redirecting it either along the horizontal (toward the left or right) or the vertical (upward or downward) axis. Also, the cost of an invalid cue can be assessed separately for the contralesional and ipsilesional visual hemifields. No trial with the invalid cue in one hemifield and the target in the other was included in this experiment. The use of such trials would not have added any information above that already available from the early work of Posner and collaborators (Posner et al., 1982, 1984) with parietal patients.

The experiment was run in six separate blocks of 64 trials each. If two blocks were run on the same day, a rest period of about 5 min was taken between them. Within each block, conditions were distributed randomly. Three factors were thus involved in this experiment: Cue validity (valid or invalid), Target location (up, down, foveal, or peripheral), and Hemifield (contralesional or ipsilesional).

## RESULTS

Figures 2 and 3 show the mean verbal RT's on trials in which the response was correct and the RT was between 150 and 3000 ms. Figure

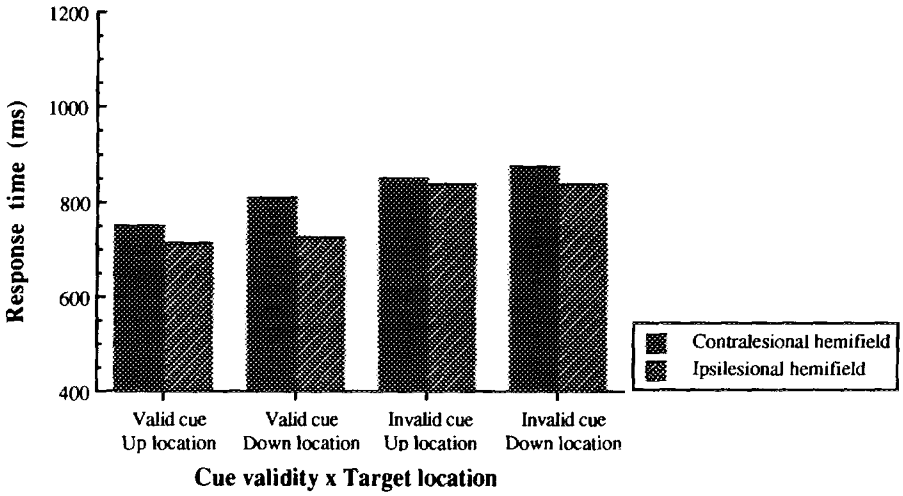


FIG. 2. Mean RT's for targets presented in the "up" and "down" locations.

2 presents RT's for the up and down target locations and Fig. 3 displays RT's for the foveal and peripheral target locations.

A three-way analysis of variance was applied to these data. Factors were Cue validity, Target location, and Hemifield. Main effects of Hemifield [$F(1, 362) = 7.1$; $p < .01$] and Cue validity [$F(1, 362) = 21.5$; $p < .001$] were significant. RT's were longer for contralesional targets than ipsilesional ones. Also, RT's were longer on invalidly cued trials than

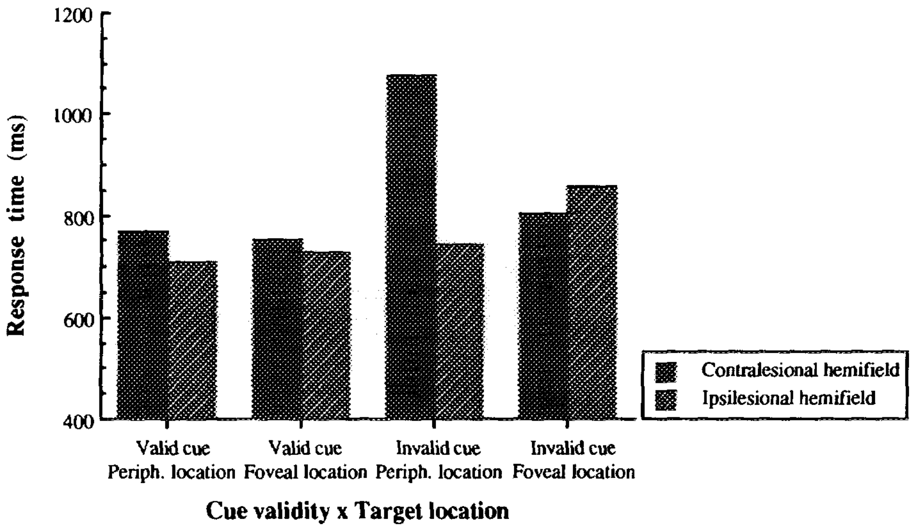


FIG. 3. Mean RT's for targets presented in the "foveal" and "peripheral" locations.

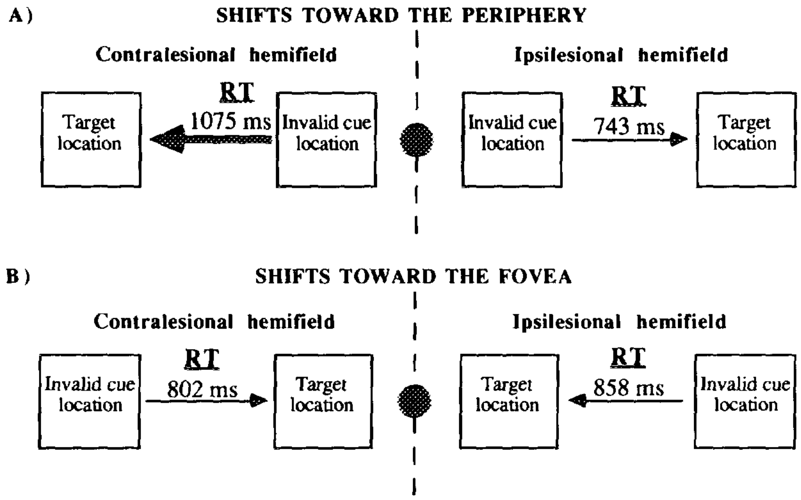


FIG. 4. Interhemifield comparison of mean RT's in conditions requiring a horizontal shift of attention from the invalid cue location to the target location. (A) The cue is foveal and the target peripheral. (B) The cue is peripheral and the target foveal.

validly cued ones. This latter effect confirms that the subject shifted her attention toward the cued location. The two-way interaction of Target location × Hemifield [$F(3, 362) = 3.4$; $p < .02$] as well as the three-way interaction of Cue validity × Target location × Hemifield [$F(3, 362) = 2.6$; $p < .05$] were also significant.

Analysis of the three-way interaction was done by breaking down the results as a function of cue validity. On validly cued trials, no significant effect was found. However, on invalidly cued trials, the interaction of Target location × Hemifield was significant [$F(3, 362) = 4.7$; $p < .005$]. Examination of simple effects showed that a significant hemifield effect was seen only with targets shown in the peripheral locations. Here, RT's were much longer for contralesional targets than for ipsilesional ones ([$F(1, 362) = 17.9$; $p < .001$]; Fig. 4A). Still, there was a trend for longer RT's with ipsilesional foveal targets than for contralesional ones following an invalid cue (Fig. 4B). By contrast, no visual hemifield effect was observed with invalidly cued targets in the up or down locations (Fig. 5).

## DISCUSSION

One important aspect of the results obtained from this right parietal patient is the absence of an effect of visual hemifield on invalidly cued trials with targets appearing in the up or down locations. This observation indicates that our subject did not show any deficit in disengaging her attention from a miscued location and redirecting it along a vertical axis.

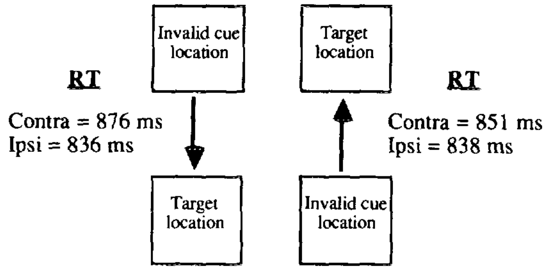


FIG. 5. Interhemifield comparison of mean RT's in conditions requiring a vertical shift of attention from the invalid cue location to the target location.

This result departs from the outcome reported by Baynes et al. (1986). Indeed, in their study, right parietal subjects showed longer RT's for contralesional targets than ipsilesional ones in a comparable situation demanding a shift of attention along the vertical. Presently, we do not have a clear explanation for this discrepancy, but it should be noted that there are several important methodological differences between the task described here and that used by Baynes et al. (1986), notably in the stimulus onset asynchrony (SOA) between cue and target, and the proportion of validly cued trials. Thus, the SOA used here was of 200 ms and cue validity was of 62.5% whereas, in the Baynes et al. study, SOA's ranged between 325 and 1575 ms and cue validity was of 80%. These procedural differences may be responsible for the discrepancy between the observations reported here and those of Baynes et al. (1986).

The second important aspect of the present results is that RT's were much longer for an invalidly cued peripheral target shown in the contralesional visual field than one shown in the ipsilesional field (Fig. 4A). This finding indicates that disengagement of attention from an invalidly cued foveal location required much more time when attention had next to be shifted in a contralesional direction as opposed to an ipsilesional direction. Such a result is congruent with those reported by Posner and collaborators (Posner et al., 1982, 1984, 1987) and argues for a directional attention deficit in parietal subjects.

A third and final aspect of the results reported here is that there was no significant difference between visual hemifields for an invalidly cued foveal target. Thus, our subject showed no significant deficit when attention had to be disengaged from an invalidly cued location to then be shifted in a contralesional direction within the ipsilesional hemifield (Fig. 4B). These observations, considered in conjunction with those described above, would imply that our right parietal subject shows a deficit in the directional disengagement of attention that is restricted to stimuli presented in the *contralesional* hemifield. However, there is a clear trend for longer RT's to an invalidly cued foveal target shown in the ipsilesional hemifield than in the contralesional one. Therefore, one may take these results to suggest that the directional disengagement deficit may be present in the ipsilesional hemifield, but is much smaller than that present in the contralesional hemifield.[2]

The results observed with invalidly cued foveal targets indicate that visual hemifield modulates—or determines—the directional disengagement deficit seen in parietal lesioned individuals. Thus, returning to the original question regarding the determinants of the disengagement deficit in parietal subjects, our results suggest that both directional and hemispatial factors may have an important role to play. That is, the disengagement deficit in our parietal subject is *directional*, since it was only found for shifts of attention from the cued location to the target location in a contralesional direction. Morever, the deficit also appears to be affected by *hemispatial* factors in the sense that it was much larger—if not, only present—for targets shown in the contralesional visual hemifield. Our analysis, presented in the Introduction, of the results reported by Posner et al. (1987) appears congruent with this conclusion.

An alternative possible view exists, however, concerning the effect of hemifield on the magnitude of the attention disorder reported here. Conceivably, the outcome is not truly determined by hemispace (left vs. right) as such, but rather is a graded function across the visual field (Rapcsak, Watson, & Heilman, 1987). According to this latter view, the magnitude of the attention deficit gradually increases with lateral displacements of the stimuli toward contralesional space and the midline separating the left and right spatial fields is, in itself, of no particular importance in determining the magnitude of the deficit. On this hypothesis, the hemifield effect we report should be considered solely as an effect of the *lateral target location* in the visual field.

Unfortunately, the observations reported here do not allow us to discriminate between a continuous gradient hypothesis and one based on a discrete function that is exclusively modulated by hemispace. However,

[2] One factor that may lead to an underestimation of the directional deficit in the ipsilesional visual hemifield is that its identification requires longer RT's for an invalidly cued foveal target shown in the ipsilesional field. However, RT's are generally longer for contralesional targets than for ipsilesional ones, even with valid cues. In addition, this main effect of hemifield may lead to an overestimation of the directional deficit in the contralesional field. Still, the main thrust of our argument does not appear to be modified when the results are examined while taking this confound into account. To verify this, we used the hemifield difference in RT's for validly cued targets as a control for the results observed with invalid cues in corresponding locations. With the use of this control, the cost brought about by an invalid cue with a target displayed in a peripheral location is greater by an amount of 265 ms in the contralesional hemifield (the difference in costs is 325 ms without the hemifield control). Also, the cost of an invalid cue with a foveal target is greater by an amount of 70 ms in the ipsilateral field (the difference in costs is 50 ms without this hemifield control). Thus, even with the use of this control for the main of hemifield on RT's, the magnitude of the directional disengagement deficit still remains nearly four times larger in the contralesional hemifield than in the ipsilesional one.

other data (Arguin & Bub, in press) gathered from the patient we have documented, along with visual search studies reported by Eglin, Robertson, & Knight (1989) suggest that, in fact, both proposals may be true. Indeed, it appears that the magnitude of the deficit exhibited by neglect subjects gradually increases with lateral displacements of the stimuli in a contralesional direction within either visual hemifield. At the same time, it also seems that hemispatial factors as such may have a special importance in modulating the attention deficit since, at least in some conditions, this gradient sharply increases when locations on either side of the midline are compared.

On the basis of the above discussion, one last comment that should be made concerns the description of the parietal deficit as one involving the disengagement of attention. As this term suggests, parietal patients have trouble pulling their attention away from an invalidly cued location and shifting toward the target location. A competing proposal, however, would be that the deficit shown by parietal patients is best described in terms of the failure of the target to capture attention when it is engaged at the wrongly cued location (Riddoch & Humphreys, 1987; Seron, Coyette, & Bruyer, 1989).

Indeed, the term "disengagement disorder" implies that parietal patients should have trouble in pulling their attention away from an invalidly cued location whenever it next has to be shifted in a contralesional direction, and this irrespective of the absolute target location in the visual field. However, we have demonstrated that a peripheral invalid cue shown in the ipsilesional hemifield which is followed by an ipsilesional foveal target leads to little or no deficit in parietal subjects. This outcome indicates that not only is the direction of the attention shift from cue to target an important factor in determining the abnormal performance, but also that the hemifield in which the target is displayed (or the lateral location of the target in the visual field) is an important factor. This effect of the target location on the magnitude of the observed impairment suggests that what has been termed thus far an attentional disengagement deficit might best be considered as a deficit in attentional capture for stimuli located on the contralesional side of the current focus of attention. The conceptualization of the disorder exhibited by parietal patients as one of attentional capture provides a reasonable framework for interpreting the difference in magnitude of the deficit between right and left hemifield targets that were preceded by an invalid cue displayed on their ipsilesional side.

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