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Shifting Visual Attention Between Objects and Locations: Evidence From Normal and Parietal Lesion Subjects

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Space- and object-based attention components were examined in neurologically normal and parietal-lesion subjects, who detected a luminance change at 1 of 4 ends of 2 outline rectangles. One rectangle end was precued (75% valid); on invalid-cue trials, the target appeared at the other end of the cued rectangle or at 1 end of the uncued rectangle. For normals, the cost for invalid cues was greater for targets in the uncued rectangle, indicating an object-based component. Both right- and left-hemisphere patients showed costs that were greater for contralesional targets. For right-hemisphere patients, the object cost was equivalent for contralesional and ipsilesional targets, indicating a spatial deficit, whereas the object cost for left-hemisphere patients was larger for contralesional targets, indicating an object deficit.

Selective attention allows us to pick out and respond to relevant information while ignoring the myriad distracting stimuli in cluttered visual scenes. Several decades of intense research have substantially advanced our understanding of the operations and neural mechanisms of selective attention. There is now broad agreement that, although attention may play a special role in integrating elementary visual features (Treisman, 1991; Treisman & Gelade, 1980), attention can also modulate the coding of these elementary features within the visual system (Chaudhuri, 1990; Prinzmetal, Presti, & Posner, 1986). Moreover, there has been increasing success in relating behaviorally identified mechanisms of attention to specific neural substrates, based on evidence ranging from the effects of brain damage (e.g., Posner, 1988), to neuroimaging in neurologically normal subjects (e.g., Corbetta, Miezen, Dobmeyer, Shulman, & Petersen, 1991), and to single-cell recording from behaving primates (e.g., Moran & Desimone, 1985).

Against this background of growing interdisciplinary consensus, one issue stands out because it has become increasingly rather than decreasingly controversial: the dispute between space-based and object-based models of visual attention (e.g., Kanwisher & Driver, 1992). The former model suggests that visual attention is directed to particular locations in a purely spatial representation of the visual field; the analogy of a spotlight is often suggested (e.g., LaBerge, 1983; Posner, 1980). In contrast, object-based models suggest that attention is directed to the candidate objects (or perceptual groups) that result from a preattentive segmentation of the visual scene in accordance with grouping principles (e.g., Driver & Baylis, 1989; Duncan, 1984). There are at least two different ways to conceive of object-based attention (Vecera & Farah, 1992). According to one interpretation, position plays absolutely no role in the selected representations, which would be object centered, in the strong sense of Marr (1982). On a less extreme view, attention is object based in the sense that positions in the field are selected together specifically because they belong to the same object (e.g., Baylis & Driver, 1992; Farah, 1990). It is this latter sense of object-based attention that has usually been advocated and that we consider in this article.

We begin with a review of existing data, which reveals evidence for both the purely space-based view of attention and the object-based view (as defined above). We note, however, that the evidence for these two views has come from very different paradigms. These previous findings suggest that there may be both space-based and object-based components to visual attention. In other words, the traditional opposition between space-based and object-based theories may be a false dichotomy because they are not mutually exclusive possibilities. We then develop a new technique for measuring both space-based and object-based attentional components within the same paradigm. We demonstrate in normal subjects that both components apply to covert orienting in a luminance-detection task. Finally, we examine the effects of parietal injury, known to disrupt covert visual orienting (e.g., Posner, Walker, Friedrich, & Rafal, 1984), on the space-based and object-spaced components.

Previous Evidence for Space-Based Attention

One of the classic paradigms for investigating visual attention uses a visual precue to indicate the likely location

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of a forthcoming target (e.g., Eriksen & Hoffman, 1972; Posner, Snyder, & Davidson, 1980). The precue facilitates detection of a subsequent target when it corresponds to that target's location (valid cue) and inhibits it when it does not (invalid cue). Explanations typically have assumed that the cue allows orienting mechanisms to allocate resources to the cued locus so that processing is enhanced for targets appearing within the area over which spatial attention is focused. For instance, Posner (1980) concluded from such cuing effects that visual attention operates "like a spotlight which enhances the detection of events within its beam" (p. 172).

The precuing paradigm has been extended in a number of investigations using normal subject populations. For example, the flexibility of the allocation mechanism has been demonstrated by using a precue delineating a general spatial region rather than a specific location (Egly & Homa, 1984; Juola, Bouwhuis, Cooper, & Warner, 1991; van der Heijden, Wolfers, Greop, & Hagenaar, 1987). In these experiments, the precue identified a circular region surrounding the fixation point. Although the exact location of the target was not known, performance was facilitated within the cued region and was inhibited both inside and outside the cued region.

An attentional spotlight is not the only spatial metaphor that has been suggested. For instance, Eriksen and Yeh (1985) suggested that attention operates like a "zoom lens" so that resources can either be tightly concentrated or diluted across a broader area. Others have suggested that attention can be allocated according to various gradients or activity distributions across space (e.g., Downing, 1988; LaBerge & Brown, 1989). All these characterizations presuppose that visual attention can operate on a purely spatial representation of the visual field.

There have been some efforts to accommodate spatial cuing effects of the kind described previously here within object-based frameworks. For instance, in one widely used version of the cuing paradigm, the target can appear within one of several outline boxes, and attention is directed by briefly brightening one of the boxes. Tipper, Driver, and Weaver (1991) argued and produced some evidence that attention might apply to the cued box rather than to the cued location per se, because the delayed inhibitory effects of uninformative peripheral cues (i.e., inhibition of return) could follow the cued box when it moved to a new location.

However, some spatial cuing effects do not yield to accounts of this kind because no object is provided for attention to lock onto before the target event. For instance, costs and benefits are observed after central cues such as arrows or digits, which specify a particular location in an entirely empty field (e.g., Posner, 1980).

Object-based theories also provide no account for the sensitivity of some cuing effects to the empty distance between cue and target. Shulman, Remington, and McLean (1979) claimed that visual attention shifts in an analog manner, traversing intervening points en route between two locations. Their interpretation of their data in these terms has been questioned (e.g., Eriksen & Murphy, 1987), but more recent evidence demonstrates that the time required to shift attention between two locations can be a function of their spatial separation (Egly & Homa, 1991).

Finally, the spatial nature of attentional deficits after brain damage appears broadly consistent with space-based models. Unilateral neglect is a relatively common disorder after unilateral brain lesions (classically of posterior association cortex) in which patients ignore information that is (in relative terms) on the side of space contralateral to their lesion. An attentional deficit is implied, because afferent pathways for the ignored information may be demonstrably intact (see Jeannerod, 1987, or I. H. Robertson & Marshall, 1993, for reviews). The contralesional nature of this attentional deficit clearly suggests damage to mechanisms of attention that operate on a spatial representation of the scene.

Posner et al. argued that neglect can result from damage to a number of distinct components in a network controlling spatial orienting. Posner et al. (1984; Posner, Walker, Friedrich, & Rafal, 1987) suggested that the allocation of spatial attention requires at least three basic operations: move, engage, and disengage. In the precuing paradigm, it is assumed that attention is moved to and then engaged at a cued location. If the target appears at an uncued location, attention first has to be disengaged from the cued location before moving to and engaging at the target location.

Posner et al. (1984; Posner, Walker, et al., 1987) found that unilateral parietal lobe damage produces a specific abnormality in the precuing task, namely exceptionally slow reactions for invalidly cued contralesional targets (see also Baynes, Holtzman, & Volpe, 1986; Morrow & Ratcliff, 1988; Petersen, Robinson, & Currie, 1989). In terms of the three-component model, this is interpreted as a specific impairment of the ability to disengage attention, whereas the ability to move and engage attention is relatively intact.

The ability to move attention, especially toward salient exogenous signals, has been associated with midbrain retinotectal pathways. Patients with progressive supranuclear palsy suffer from degeneration of the superior colliculus and peritectal regions. Vertical eye movements are impaired early in the disease. Patients with the disorder also show a characteristic abnormality in the cuing paradigm that differs from the pathological orienting pattern found in parietal patients. When attention is vertically cued, the benefit for validly cued targets is abnormally slow to emerge, consistent with a difficulty in moving attention to the locus of the cue (Posner, Cohen, & Rafal, 1982; Rafal, Posner, Friedman, Inhoff, & Bernstein, 1988).

Finally, there is evidence from cuing studies that the pulvinar nucleus of the thalamus may play a role in the hypothesized engage operation. Patients with unilateral thalamic hemorrhages are abnormally slow for both valid and invalid contralesional targets, which is taken as an impairment in engaging attention on contralesional space (Rafal & Posner, 1987). Furthermore, positron emission tomography studies in normal subjects have provided converging evidence that the pulvinar nucleus functions in engaging attention to filter out distractors that flank a target (LaBerge & Buchsbaum, 1990).

It is not yet clear whether disengaging and engaging attention are separate and independent elementary operations rather than opposing aspects of the same process. Cohen and Farah (1991) carried out simulation studies with a simple connectionist architecture that modeled a deficit in disengaging attention. Their model did not require a separate, specific "disengage operation," leading them to suggest that engaging and disengaging attention may be different sides of the same coin, reflecting the extent to which an attentional network is captured by stimulation from a particular region. Although such details remain controversial, the importance of the three-component model for our current concern is that it successfully accommodates the effects of various kinds of brain injury on performance in the precuing paradigm within a purely space-based framework.

In summary, the precuing paradigm has been widely used in investigations of both normal and neurological populations. It has provided evidence for spatial mechanisms of selection and has been used to delineate the nature of the component processes and their associated neural systems. However, in its standard form, the paradigm does not provide much opportunity for object-based selection processes to manifest themselves. Researchers have begun to investigate the issue of object-based selection with paradigms that substantially differ from the precuing procedure.

Previous Evidence for Object-Based Attention

Until recently, widespread adherence to the spotlight metaphor for attention has resulted in relatively few investigations contrasting attention to locations with attention to objects. Duncan's (1984) seminal investigation revealed the importance of this distinction. Duncan's displays consisted of an outline box with another line superimposed across it, briefly presented and followed by a mask. The box was short or tall and had a gap in its left or right side; the line was dashed or dotted and had a positive or negative slope. Subjects had to judge one or two of these four properties. They could judge two properties of the same object (e.g., "right" and "short" for the box) as readily as one. However, there was a decrement in performance if they had to judge two properties from different objects (e.g., "right" for the box and "dotted" for the line). This suggests a difficulty in simultaneously attending to two objects. The pattern of results is difficult to account for in purely space-based terms because the objects were superimposed in the same spatial region, and the two attributes of the box (gap and height) were at least as far apart as the gap in the box and the attributes of the line (because box height was specified by the vertical extremes of the display).

Watt (1988) suggested, however, that Duncan's (1984) within-object pairs of attributes happened to be closer in the spatial frequency spectrum than the between-objects pairs and that Duncan's results might therefore imply spatial-frequency restrictions on attention rather than object-based restrictions. However, this suggestion cannot accommodate Baylis and Driver's (1993) object-based findings. Baylis and Driver used an ambiguous display, analogous to Rubin's celebrated faces–vase figure, which could either be seen as two objects against a central background or as a central object against flanking background. Color instructions induced subjects to make either the two-object or single-object interpretation. Comparing the edges of the vase–faces was more difficult when these edges were seen as belonging to two objects (the faces) rather than one (the vase). This demonstrates a difficulty in simultaneously attending to two objects, and because an identical display was used in the one- and two-object conditions, the result cannot be explained in terms of differential locations or spatial frequencies.

Although Duncan (1984) and Baylis and Driver (1993) examined the impact of object segmentation on divided attention, Kramer and Jacobson (1991) examined its influence on selective attention in an elegant variation of Eriksen's response-competition paradigm (e.g., Eriksen & Hoffman, 1972). The task was to indicate whether a vertical line, centered at fixation, was dashed or dotted. Irrelevant dashed or dotted vertical lines were located to the left and right of the target line, with their texture either compatible or incompatible with the central target line. The critical manipulation was whether the flanking lines were parts of the same object as the target line (in which case they were connected to it by horizontal lines) or parts of different objects.

Kramer and Jacobson's (1991) results supported Duncan's (1984) claim that attention is directed to objects. They found that response competition was greater when the flanking lines were parts of the same object as the target line, even though the separation between target and flankers was identical in the same- and different-object conditions. Kramer and Jacobson also manipulated the spatial separation of central target (at fixation) and flanking distractors (in the periphery) to measure any influence of purely spatial factors. However, separation between target and distractors was confounded with the retinal eccentricity of the distractors under this manipulation, so the spatial aspects of their findings may have resulted from acuity limits rather than attentional factors.

Driver and Baylis (1989) also reported response-competition data from a variant of the flanker paradigm that are problematic for purely space-based models of visual attention. They found that distant distractor letters, which moved with a target letter, produced more interference than distractors that were closer but did not share the target's motion. This suggested that attention is directed to the candidate objects, which result from preattentive grouping, rather than to locations per se. Failures to replicate this result have been reported (Kramer, Tham, & Yeh, 1991), suggesting that it may closely depend on the particular motion and location parameters involved. However, Baylis and Driver (1992) found that grouping by color and good continuation can produce similar results under some circumstances, supporting their general claim that the distribution of attention is not solely determined by locational factors.

Two other investigations have obtained data with moving stimuli that also support object-based mechanisms of selection. As mentioned earlier, Tipper et al. (1991) found that the delayed inhibitory aftereffects of uninformative peripheral cues (inhibition of return) can follow the cued box to a new location if it moves, suggesting that a specific object, rather than location, is inhibited. Tipper, Brehaut, and Driver (1990) reached a similar conclusion for the negative priming effect (i.e., the performance cost found when a previously ignored object has to be attended).

As in the case of location-based selection, the attentional impairments of neurological patients have clarified the theoretical importance of object-based selection. As discussed earlier, patients with unilateral neglect ignore contralesional stimuli. In a less severe form known as extinction, neglect of contralesional stimulation occurs only when there is simultaneous ipsilesional stimulation. The contralesional nature of both these pathological signs demands an explanation in terms of impairment to a space-based component of attention. However, recent evidence suggests the contribution of an object-based component as well.

Farah, Wallace, Brunn, and Madigan (1989) required neglect patients to read letters that were randomly located on a page. These letters were surrounded by two irrelevant elliptical outlines. The two ellipses did not overlap and were either vertically oriented with one on the left and one on the right of fixation (to give one contralesional ellipse and one ipsilesional) or horizontally oriented with one above and one below fixation (so that each ellipse extended both contralesionally and ipsilesionally). In both cases, some of the letters appeared inside each ellipse. With the horizontal format (i.e., when each ellipse occupied both contralesional and ipsilesional space), the patients reported more of the contralesional letters and more frequently began their search on the contralesional side. This suggests that the spatial deficit was modulated when a single global object extended into the neglected side.

Driver and Halligan (1991) also suggested that neglect is affected by segmentation of a scene into objects. They found that a right-hemisphere patient with left neglect omitted details on the left of a vertically elongated shape even when the shape was tilted 45° so that these details fell to the patient's right. Similarly, Driver, Baylis, and Rafal (1992) found that a left-neglect patient with right-hemisphere damage missed more details on the left of a perceptual figure to his right than on the right of a perceptual figure further to his left.

In the studies by Driver et al. (Driver, Baylis, & Rafal, 1992; Driver & Halligan, 1991), patients apparently neglected information on the left of a perceptual object. In contrast, patients in Farah et al.'s (1989) study appeared either to attend to the entire global object or to neglect it completely, raising something of a paradox. One obvious difference between the stimuli used by these different research groups is that the objects in question were vertically extended in the Driver et al. studies (yielding a principal axis that divided left from right) but horizontally extended in the critical conditions of Farah et al.'s studies. Whether or not this difference or some other factor resolves the paradox, both sets of study demonstrate that, although neglect is *spatial in that the impairment* always applies to contralesional information, it is also sensitive to object segmentation. Any explanation in terms of space-based or object-based theories alone is therefore likely to be inadequate; instead, both space-based and object-based components must be invoked.

Perhaps the most dramatic evidence for object-based selection is seen in patients with bilateral lesions of the parietal lobes who manifest simultaneous agnosia. In this classical Balint's syndrome, the patient can see only one object at a time (e.g., Holmes & Horax, 1919). This occurs even if the objects spatially overlap (e.g., glasses on a face), suggesting that the restriction is object based. Shown a cross filling a circle, the patient will report one or the other. Shown a six-pointed star constructed of two outline triangles of different color, the patient may see only one triangle (e.g., Luria, 1964). No purely space-based model of attention can accommodate the most striking phenomenon in these patients: They seem unable to disengage from one object to shift attention to another, even when both objects are in the same location.

Humphreys and Riddoch (in press) provided elegant experimental evidence that formally confirms the object-based restriction in Balint's syndrome suggested by clinical experience. Two Balint's syndrome patients were shown 32 circles that were all red, all green, or half red and half green. The task was to report whether each display contained one or two colors. The critical test was when the displays contained two colors. In one condition, the spaces between the circles contained randomly placed black lines. In two other conditions, the lines connected either pairs of same-colored circles or pairs of different-colored circles. Both patients were better at correctly reporting the presence of two colors when the lines connected different-colored pairs of circles. Circles connected by a line are perceived as a single object (e.g., as a dumbbell). When each object contained both red and green, the patients could report the presence of the two colors. If each object contained only a single color, the patients had great difficulty, because their attention tended to lock onto a single object.

Summary

The evidence we have considered indicates a visual attention system that allows us to select locations, objects, or both, as relevant sources of information. Any comprehensive theory of visual attention will therefore require both space-based and object-based components. There are several possible ways in which these different components could be theoretically integrated. For example, one might propose interactive activation between an orienting system that selectively activates particular locations and a segmentation system that links disparate locations as a result of grouping operations applied to the current input (Farah, Wallace, & Vecera, 1993; Humphreys & Riddoch, in press, 1993). Alternatively, one might hypothesize that some orienting systems (e.g., cortical systems controlling voluntary orienting) operate on segmented objects, whereas others operate on raw locations (e.g., subcortical systems responsible for automatic orienting). To illustrate a further hypothetical possibility, one might suggest that whether or not attention is space based or object based depends solely on the level of visual representation demanded by the task. Indeed, Vecera and Farah (1992) proposed that attention is object based only when the task involves shape judgments that use object-centered representations (in the sense of Marr, 1982). In contrast, they predicted that attention will be space based when the task involves judgment of visual features such as color or brightness that are coded in an array format by visual cortex.

The present investigation proceeds from a framework that includes both space-based and object-based components to visual attention. However, very little is known about when these components apply, and currently there are few empirical constraints on how their interaction should be envisaged. In comparison with the spatial mechanisms, the nature of the object-based mechanisms and their underlying neural systems remains poorly understood. We devised our experiments as a first step toward addressing these issues.

With few exceptions (e.g., Kramer & Jacobson, 1991), previous research has examined space-based and object-based components of attention in very different paradigms. It is not clear whether both can apply in the same situation. Our first experiment was designed to measure both space-based and object-based components of covert visual orienting within a single task—a modified spatial precuing paradigm. We cued subjects to one location within an object and examined performance differences for the cued part of that object versus an uncued part. This yielded our measure of the spatial component to visual attention, because detecting a target at the uncued part of the cued object required an attentional shift in location but did not require attention to be shifted to another object. We also compared performance on the uncued part of the cued object with processing for parts from a simultaneously presented uncued object. The probed parts of the uncued object were the same distance from the precue as the uncued part of the cued object and had the same retinal eccentricity. Comparing performance for these conditions therefore allowed us to compare within- and between-objects shifts of attention, which were comparable in purely spatial terms. This comparison afforded a measure of any performance cost in shifting attention from one object to another. We tested both normal subjects (Experiment 1) and neurological patients with unilateral lesions of left or right posterior association cortex (Experiment 2). All of the patients had parietal lobe damage. As discussed previously, parietal lobe patients have been extensively used to investigate deficits in the disengage operation of spaced-based selection. We were interested in whether the parietal lobe also has a role in object-based selection.

Experiment 1

The purpose of Experiment 1 was to examine how cuing one part of an object affects the processing of other parts of that object and equidistant parts from another object. We presented two outline rectangles either above and below fixation or to the left and right of fixation. The task was to detect the "filling in" of one of the four ends of the two rectangles to yield a solid square at that end. Before the appearance of this square, one of the ends of a rectangle was brightened to induce covert orienting. On valid-cue trials, the square then appeared at the cued end of the cued rectangle (75% of all trials). On the invalid-cue trials, the square appeared either at the uncued end of the cued rectangle (within-object shift) or at an equidistant end of the uncued rectangle (between-objects shift). The within- and between-objects shift trials were matched for distance and (across trials) for direction from the cued corner. Thus, any performance difference between them should be attributable to a nonspatial component of visual attention involved in shifting attention between objects.

Method

Subjects. The subjects were 15 paid volunteers who had been recruited from a local community college.

Apparatus. Data collection was controlled by an IBM-compatible 386 personal computer with a microswitch fire button on a joystick as the interface using the game port. Stimuli were presented on an NEC Multisync 3D color monitor at a viewing distance of about 61 cm.

Stimuli. The stimuli were graphics characters programmed in Microsoft QuickBASIC 4.5 in a 640 × 480 pixel VGA mode. The fixation point, rectangles, and target were gray, and the cue was white. The fixation point was a plus sign (+), which subtended about 0.1° × 0.1°. Each rectangle subtended about 1.7° × 11.4° with a stroke of approximately 0.2° and was centered 4.8° from fixation. The target was a solid square about 1.7° on each side. The cue also had a 0.2° stroke and consisted of whitening three sides of an imaginary outline square, which overlapped one end of a rectangle and had the same dimensions as the target square.

Procedure. Each trial began with a fixation display containing the fixation cross and two rectangles. The rectangles appeared either to the left and right of fixation or above and below fixation. In the vertical objects condition, the rectangles were oriented as columns centered about 4.8° left and right of fixation, and in the horizontal-objects condition, the two rectangles were oriented as rows centered about 4.8° above and below fixation. The four ends of the two rectangles (i.e., the possible target-square locations) occupied precisely the same locations in these two conditions (see Figure 1 for examples), about 6.8° from fixation.

After this gray fixation display had been presented for 1,000 ms, the cue was superimposed on it for 100 ms. The cue was a brightening (i.e., change from gray to white) at one of the four ends of the two rectangles. After 100 ms, the cued end returned to its original gray color, and the fixation display was presented for another 200 ms. The target gray square (or nothing on catch trials) was then superimposed on the fixation display at one of the four ends of the two rectangles. Thus, target presentation took the form of a square "filling in" at one end of a rectangle. The target remained visible until the subject responded by pressing a single fire button on the joystick or for 2,000 ms if there was no response. This terminated the trial, and the next began after a 500-ms intertrial interval during which the screen was blank.

The subjects' task was to press the single button as rapidly as possible [yielding a simple reaction time (RT)] whenever a target was detected at any of the four rectangle ends and to withhold responses on the occasional catch trials with no target. The sub-

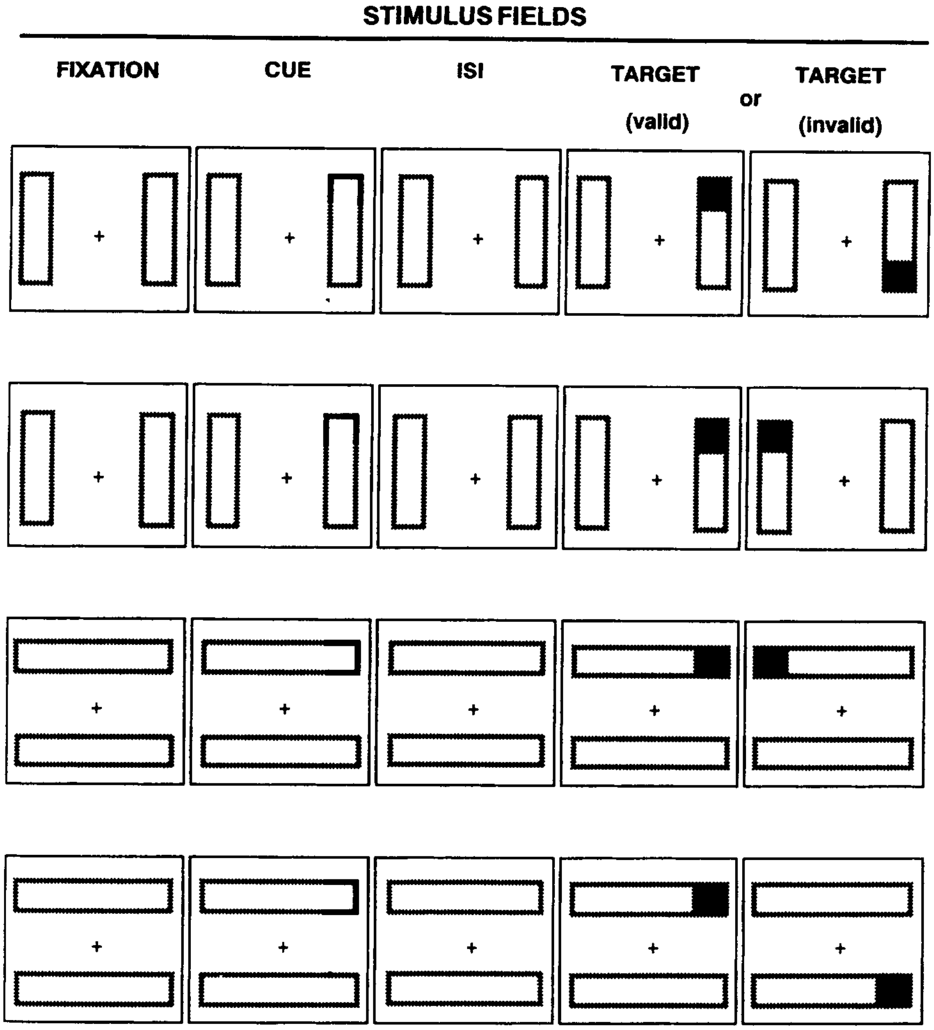

Figure 1. Examples of the typical sequence of events (running left to right) within trials from the major conditions of Experiments 1 and 2. The heavy black lines in the panels of the second column represent cues. The small filled squares in the panels of the last two columns represent subsequent targets. The invalidly cued target illustrated at the right of the top row requires a within-object shift of attention from the preceding cue and likewise for the invalidly cued target in the third row. In contrast, the invalidly cued targets illustrated in the second and fourth rows require a between-objects shift of attention from the cue. (ISI = interstimulus interval.)

jects were told that response latency would be recorded but that it was important to minimize the number of errors. A 500-ms feedback beep was presented if a subject made an anticipation response (RT < 150 ms) or a false alarm. Subjects were strongly cautioned to maintain fixation throughout each trial. Eye position was monitored visually by the experimenter during the practice phase.

The order of trials was randomized by the computer for each subject. There were eight blocks of 96 trials each, and a rest period was offered between them. Before the experimental trials, each subject was given a set of practice trials randomly selected from the experimental conditions. The experimenter explained the task while practice trials were being displayed. The practice session was terminated when the subject had made 20 consecutive correct responses without an eye movement.

Design. The target appeared at the cued rectangle end on 75% of the trials (valid cue) and at an uncued end on 25% of the trials (invalid cue). The critical manipulation on invalid-cue trials was whether the target appeared in the cued rectangle or at the equidistant end of the uncued rectangle. These two possibilities were equally likely. On all invalid-cue trials, the target appeared in a rectangle end, which was a reflection from the cued end across either the horizontal or vertical meridian. That is, the target never appeared at the rectangle end diametrically opposite the cued end. An example of each type of invalid-cue trial is shown in Figure 1 for both the vertical objects and horizontal objects conditions.

Each subject was shown 640 target-present trials consisting of 480 valid-cue trials (2 rectangle orientations x 4 target locations x 60 repetitions) and 160 invalid-cue trials. For each of the two types of invalid-cue trials, there were 10 repetitions for each of the eight cues (2 rectangle orientations x 4 target locations). There were also 128 catch trials consisting of 16 repetitions of each of the eight cues.

Results

RTs of less than 150 ms were excluded as anticipations, and false-alarm RTs were not analyzed. To increase the power of the analyses, for each condition, the data for targets in the upper and lower left locations were combined, as were the data for the upper and lower right locations. The mean hit rate on target-present trials was 0.983, and the mean false-alarm rate on catch trials was 0.051.

Subject medians were initially analyzed in a three-way, within-subjects analysis of variance (ANOVA) with cuing (valid or invalid), target field (left or right), and orientation of rectangles (vertical or horizontal) as factors. There was a significant main effect of cuing (mean valid cue = 324 ms; mean invalid cue = 364 ms), $F(1, 14) = 31.83$, $p < .001$. Taking the excluded data into account, these valid- and invalid-cue means were based on 98.2% and 98.5% of their respective data points. There were no other significant sources of variance in the initial ANOVA.

This analysis showed that the conventional benefit of valid cuing was observed for target detection. However, the analysis did not consider the critical comparison for the present study, namely whether the invalid-cue trials required a shift of attention (from cue to target) within the same object or between objects (to one end of the uncued rectangle). To examine this issue, an analysis of RT costs for the two kinds of invalid-cue trial relative to the valid-cue trial baseline was conducted. This afforded a comparison of performance on invalid-cue trials when the target appeared in the cued rectangle versus the uncued rectangle. For each subject, the cuing effect (strictly the cost plus benefit, but hereafter called cost for convenience) for each of the invalid-cue conditions was calculated by subtracting from its median the median for the corresponding valid-cue condition (i.e., target field and orientation of rectangles were held constant for each comparison). Note that because the very same valid-cue RT was subtracted from the within-object invalid-cue RT and the between-objects invalid-cue RT, any object effect must be caused by performance on the invalid-cue trials.

A three-way ANOVA was conducted on the resulting data, with rectangle (cued or uncued), target field (left or right), and direction of the required shift in attention from cued location to target location (horizontal or vertical) as within-subjects factors. Only the main effect of rectangle was significant, $F(1, 14) = 14.77$, $p < .005$. As shown in Figure 2, the cost for responding to invalidly cued targets appearing in the uncued rectangle ($M = 47$ ms) was greater than that for invalidly cued targets in the cued rectangle ($M = 34$ ms). These mean costs were based on 98.5% and 98.4% of their respective data points. The other sources of variance in the ANOVA were unreliable.

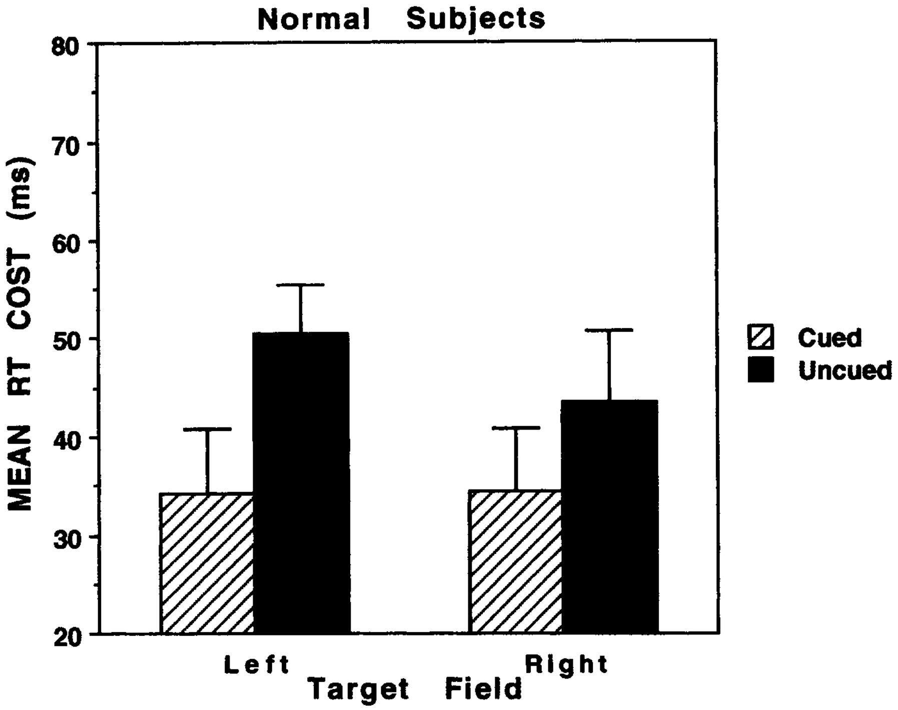

Figure 2. Means of the median costs from invalid cuing (given by invalid-cue reaction time, or RT, minus valid-cue RT) for the normal observers in Experiment 1. Data are shown as a function of the two invalid-cue conditions (i.e., whether the rectangle that contained the target was cued or uncued) and of target field (left or right). The mean of the median valid-cue RTs that were subtracted from invalid RTs to yield the illustrated costs was 324 ms for both left targets and right targets.

Discussion

The results demonstrate both space-based and object-based components of visual attention in normal observers within the same task. RT to detect a luminance increment at one location within an object was delayed if covert orienting had been directed by peripheral brightening to a different location within the same object. This implies a time cost when attention must be shifted to a new locus in an attended object and thus demonstrates a purely spatial component of selection. However, detection was significantly delayed if attention had to be shifted to part of a different object. Because the distance and direction of between-objects shifts were identical across trials to within-object shifts (and retinal eccentricity was also matched), the additional cost of between-objects shifts must reflect a time cost for shifting attention between objects, thus demonstrating an object-based component to covert orienting.

Our literature review revealed that previous evidence for space-based and object-based components has typically come from markedly different tasks. As far as we know, the present experiment provides the first evidence that space-based and object-based components of covert orienting can both apply in the same situation, and it supports accounts of visual attention that incorporate both components (e.g., Kramer & Jacobson, 1991). These findings also place constraints on models of how the components interact. For instance, they seem problematic for Vecera and Farah's (1992) suggestion that space-based attentional limitations will be found in one set of tasks and object-based limitations in another, nonoverlapping set of tasks. Our data seem to disconfirm their prediction that object-based limitations will not be found in visual tasks that can be performed on the basis of array-format representations. The present task of detecting salient luminance increments should fall into this category because it is well established that luminance information is represented in spatiotopic maps within visual cortex. However, we observed an object-based component of selection in the present, simple detection task in addition to a space-based component.

In subsequent experiments (Rafal, in press), we have confirmed that the object-based component revealed here does not depend on our use of bracket-shaped outline cues. It is still observed when the two rectangles are replaced by two columns or two rows of collinear circles, with circular outline cues and solid targets appearing at the end circles. That is, the between-objects cost is still found when within-object shifts (strictly, shifts within a perceptual group in the case of the aligned circles) actually require more contours to be traversed than between-groups shifts. Thus, the costs we obtain for shifting attention between objects or groups cannot be attributed to any difficulty in moving attention across contours in the present displays. Likewise, the object- and space-based components are still observed when eye-movement monitoring is implemented throughout testing with infrared trackers.

In the next experiment, we applied our method for measuring both space-based and object-based components of covert orienting to the problem of identifying the neural substrates of object-based selection. The task used in Experiment 1 was used with a group of patients who had suffered unilateral damage to parietal cortex. On the basis of prior research (Baynes et al., 1986; Morrow & Ratcliff, 1988; Petersen et al., 1989; Posner et al., 1984; Posner, Walker, et al., 1987), these patients were expected to show a specific deficit in the spatial component of attention; detection should be abnormally slow for contralesional targets after an invalid cue. The critical question was whether this contralesional difficulty would be abnormally exacerbated when detecting the contralesional target requires an attention shift between objects as well as between locations. This would indicate that the parietal lobe is involved in shifting attention between objects as well as between locations.

Experiment 2

The procedure and design were identical to those of Experiment 1, allowing us to examine any neuropsychological deficits in both the space- and object-based components of visual attention that we had identified in normal subjects. Our two groups of patients had either left- or right-hemisphere lesions in posterior association cortex. The lesion included the parietal lobe in all patients.

Previous investigations of humans with unilateral parietal lesions have shown them to have a pathological spatial disengage operation (Baynes et al., 1986; Morrow & Ratcliff, 1988; Petersen et al., 1989; Posner et al., 1984; Posner, Inhoff, Friedrich, & Cohen, 1987; Posner, Walker, et al., 1987). In the original Posner et al. (1984) study, the critical result linking the parietal lobe with the disengage operation was a dramatically slowed RT to invalidly cued targets at contralesional field locations. When the ipsilesional field was cued and the target appeared in the contralesional field, the cost was much greater than when the contralesional field was cued and the target appeared in the ipsilesional field. In contrast, RT functions for validly cued contralesional and ipsilesional field locations were similar over a large range of intervals from cue onset to target onset. This latter finding implies that the move and engage operations were similar in the contralesional and ipsilesional fields. The greater cost of invalid cuing for the contralesional field was therefore attributed to a pathological disengage operation.

A further finding has been that the right parietal lobe seems more specialized for disengaging spatial attention than the left parietal lobe. Right parietal lesions tend to produce a greater deficit in the disengage operation than do left parietal lesions (Petersen et al., 1989; Posner et al., 1984; Posner, Walker, et al., 1987). Furthermore, the disengage deficit is occasionally absent with left parietal lesions (Baynes et al., 1986; Morrow & Ratcliff, 1988).

All these previous studies on the effect of parietal injury considered only potential abnormalities in spatial components of attention. The present experiment examined both space-based and object-based mechanisms after parietal injury within a single task. Evidence favoring a disengage role for the parietal lobe in space-based selection (i.e., as previ-

Table 1
Clinical Data for Patients in Experiment 2

			Lesion				Clinical signs[a]				
Patient	Age (years)	Sex	Hemisphere	Cause	Vol	Vintage	Par	Sen	Neg	Ext	Aph
HS	77	M	Right	Stroke	109	5 yr	+	+	–	–	–
KE	42	F	Right	Tumor[b]	46	6 yr	–	–	–	–	–
JR	44	M	Right	Trauma	6	20 yr	–	–	–	–	–
CS	53	M	Right	Stroke	43	6 mo	+	+	–	–	–
GB	44	M	Right	Trauma[c]	58	17 yr	–	–	–	–	–
WW	57	M	Right	Stroke	58	1 yr	+	+	–	–	–
JW	69	M	Right	Stroke	26	2 yr	–	–	–	–	–
NJ	55	M	Right	Stroke	80	3 yr	+	–	–	–	+
DL	59	M	Left	Stroke	24	6 yr	–	–	–	–	+
FO	63	M	Left	Stroke	25	8 yr	–	–	–	–	+
EH	66	M	Left	Stroke	73	8 yr	+	+	+	+	+
DH	65	M	Left	Trauma[d]	26	40 yr	–	–	–	–	–
FR	64	M	Left	Stroke	16	1 mo	–	–	–	–	+

Note. Vol = volume (cc); Par = hemiparesis; Sen = hemisensory deficit; Neg = visual hemineglect; Ext = visual extinction; Aph = aphasia; M = male; F = female.
[a] At time of testing. [b] Tumor resection. [c] Hematoma resection. [d] Shrapnel wound.

ously observed) would be a greater overall cost for invalidly cued targets in the contralesional versus ipsilesional field for both within- and between-objects shifts. Evidence for a role in nonspatial components of visual attention would be provided if any additional cost for between-objects versus within-object shifts interacted with target field. That is, we expect the object effect found for normal subjects in Experiment 1 to be exaggerated for targets in the contralesional field relative to the ipsilesional field if parietal lobe damage leads to particular difficulties in shifting attention between objects.

Method

Subjects. The subjects were 13 recruited patients who had unilateral lesions affecting posterior association cortex including parietal lobe. Patients with florid clinical signs of neglect following acute stroke were not included.[1] One of the subjects (Patient EH) was a chronic patient who still showed some residual signs of neglect on line cancellation, line bisection, and so on. None of the patients had dementia, identifiable mental illness, debilitating medical problems, or coexisting drug or alcohol abuse problems. All were active participants in a variety of neurobehavioral research studies. All were men except for Patient KE, and all were right-handed except for Patient EH. They ranged in age from 42 to 77 years, with a mean of 58 years. In 8 patients, the lesion was in the right hemisphere and for 5 it was in the left hemisphere.

Table 1 provides clinical information for the patients in each group. Four patients in the left-hemisphere lesion group had strokes, and 1 had a penetrating head injury. Five patients in the right-hemisphere lesion group had strokes, 1 had a tumor resection, and in 2 patients the lesion was from a closed head injury. One patient in the right-hemisphere lesion group had a stroke 6 months before testing, and 1 patient in the left-hemisphere lesion group had a stroke 1 month before testing. In the other patients, the occurrence of the brain injury had been at least 1 year before testing. The mean lesion volumes for the two groups were not significantly different ($M = 52$ cc for the right-hemisphere group; $M = 33$ cc for the left-hemisphere group), $t(11) = 1.237$, $p > .2$. Neuroimage reconstructions depicting the extent of the lesion in each patient are shown in Figure 3. The method for reconstruction from the magnetic resonance imaging or computed tomography scans is described in detail elsewhere (Frey, Woods, Knight, & Scabini, 1987).

One right-hemisphere patient and 4 left-hemisphere patients had aphasia. Four of the right-hemisphere patients and 1 of the left-hemisphere patients had contralesional motor weakness. Three patients in the right-hemisphere lesion group were taking anticonvulsant medication, but only 1 (Patient JW) had an active seizure disorder. None of the left-hemisphere lesion group was taking anticonvulsants.

Procedure and design. As mentioned, the procedure and design for Experiment 2 were similar to those for Experiment 1.

Results

As with the normal subjects, RTs of less than 150 ms were excluded, because anticipations and false-alarm RTs were not analyzed. In the interest of increasing power, data were again pooled for the upper and lower left locations and for the upper and lower right locations. For patients with right-hemisphere lesions, the mean hit rate on target trials was 0.987 and the mean false-alarm rate on catch trials was 0.033. For the left-hemisphere patients, the hit rate was 0.972 and the false-alarm rate was 0.137.

The RT medians for correct responses were initially analyzed in a four-way mixed ANOVA. The within-subjects factors were target field (ipsilesional or contralesional),

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[1] These selection criteria were adopted because we suspect, on various grounds, that acute, florid neglect is a multicomponent syndrome that reflects dysfunction in several areas beyond the immediate focus of a parietal lesion (because of transient ischemia and other effects). Therefore, we consider clinically stable groups of anatomically selected patients more suitable for the purpose of relating a specific attentional operation to a particular brain area. This issue is taken up in the General Discussion.

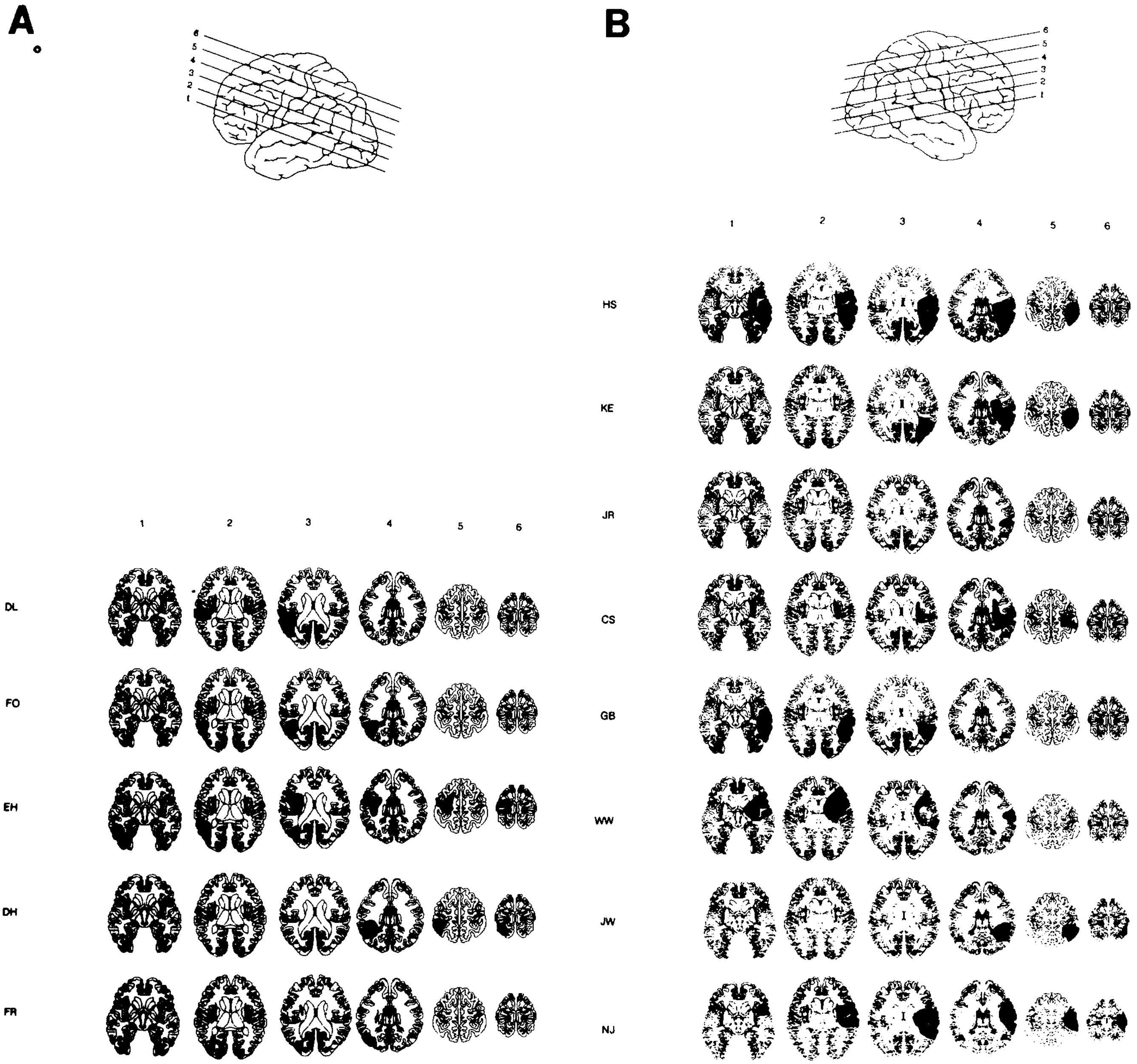

Figure 3. Reconstructions of the brain damage in the 13 patients from the left-parietal group (A) and the right-parietal group (B) in Experiment 2. The extent of the lesion is shown in black for each patient. The lines on the lateral views indicate the corresponding axial cuts. The reconstructions are based on computed tomography scans or magnetic resonance imaging scans.

cuing (valid or invalid), and rectangle orientation (horizontal or vertical). Side of lesion (left or right) was a between-subjects factor. The analysis showed a main effect of field, $F(1, 11) = 9.24$, $p < .025$. Responses to targets in the ipsilesional field ($M = 458$ ms) were faster than those to targets in the contralesional field ($M = 493$ ms). The main effect of cuing was also significant (M valid cue = 438 ms; M invalid cue = 513 ms), $F(1, 11) = 31.42, p < .001$. These two factors also interacted, $F(1, 11) = 5.15$, $p < .05$. The cost of invalid cues was greater for contralesional targets ($M = 89$ ms) than for ipsilesional targets ($M = 60$ ms).

The main effect of side of lesion and all interactions involving side of lesion were unreliable in this analysis (all $ps > .2$). Overall, left-hemisphere patients were 32 ms slower on valid-cue trials (M left hemisphere = 458 ms; M right hemisphere = 426 ms; $p > .6$), and 30 ms slower on invalid-cue trials (M left hemisphere = 531 ms; M right hemisphere = 501 ms; $p > .7$). Figure 4 shows the mean RTs

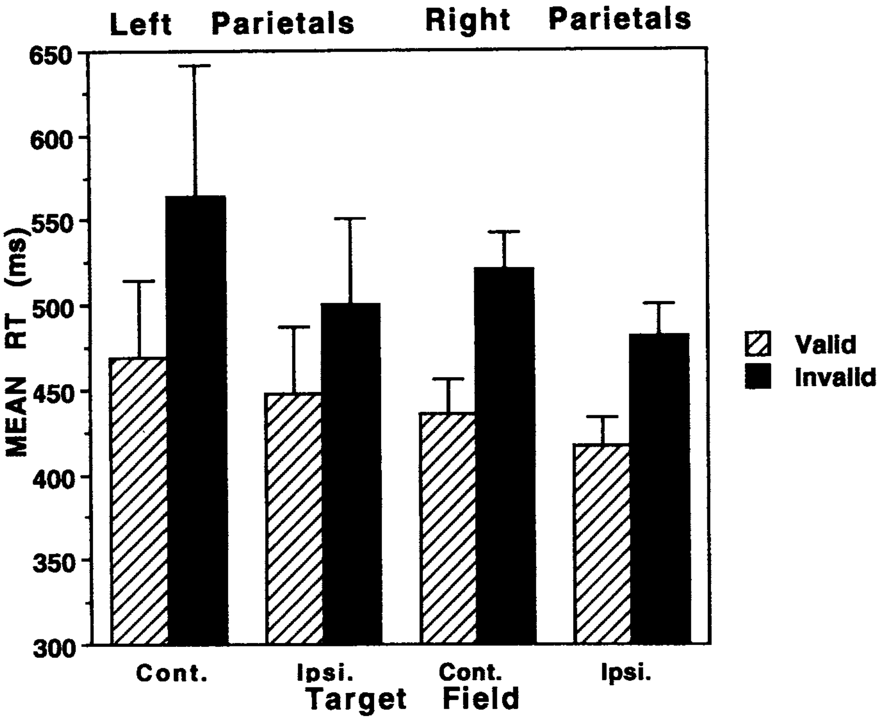

Figure 4. Means of median reaction times (RTs) for the left- and right-parietal groups in Experiment 2. The RTs are shown as a function of cuing (valid or invalid) and target field. Cont. = contralesional; Ipsi. = ipsilesional. Between-objects and within-object invalid-cue trials are pooled.

for the left- and right-hemisphere patients in the major conditions disregarding the object manipulation. These analyses did not consider whether invalid-cue trials required within- or between-objects shifts of attention. Accordingly, as in Experiment 1, the cuing effects were analyzed further to determine whether different costs emerged for invalid-cue trials, in which the cued rectangle contained the target, versus invalid-cue trials, which required a shift of attention to another object. Cuing effects were calculated in the same manner described for the normal subjects in Experiment 1 (i.e., by subtracting valid-cue RTs from between-objects or within-object invalid-cue RTs to comparable targets). Note that because the same valid-cue RT is subtracted from the invalid-cue RTs for the within- and between-objects conditions that are compared, any object effect must be attributable to performance on the invalid-cue trials. The resulting costs from invalid cues were analyzed in an ANOVA containing side of lesion (left or right) as a between-subjects factor and target field (ipsilesional or contralesional), rectangle (cued or uncued), and direction of the required attention shift (horizontal or vertical) as within-subjects factors.

Overall costs were greater in the contralesional field (M = 97 ms) than in the ipsilesional field (M = 62 ms), $F(1, 11) = 8.05, p < .025$. Costs were also greater when the target appeared in the uncued rectangle (M = 94 ms) versus the cued rectangle (M = 65 ms), $F(1, 11) = 16.04, p < .005$. There was also an interaction between target field and cued versus uncued rectangle, $F(1, 11) = 9.31, p < .025$. The disadvantage for responding to invalidly cued targets appearing in the uncued rectangle versus the cued rectangle was greater in the contralesional field (mean difference of 12 ms for ipsilesional targets, 45 ms for contralesional targets).

The major finding was a significant three-way interaction among side of lesion, target field, and cued versus uncued rectangle, $F(1, 11) = 10.17, p < .01$. To investigate this interaction further, separate analyses were performed for the left- and right-lesion groups with target field and cued versus uncued rectangle as the factors. For the right-hemisphere patients, there were significant effects of both field and rectangle. Costs were reliably greater in the contralesional field (M = 87 ms) than in the ipsilesional field (M = 65 ms), $F(1, 7) = 8.86, p < .025$. The effect of cued versus uncued rectangle was very similar to the normal subjects in Experiment 1. The cost for responding to invalidly cued targets appearing within the uncued rectangle (M = 88 ms) was greater than for targets appearing in the cued rectangle (M = 64 ms), yielding a significant 24-ms cost for shifting attention between objects, $F(1, 7) = 23.45, p < .005$. Field and rectangle did not interact for the right-lesion patients ($F < 1$). That is, the cost of shifting attention between objects was no greater for targets in the contralesional field (M = 27 ms) than for targets in the ipsilesional field (M = 21 ms).

In contrast to the right-hemisphere patients, the only significant source of variance in the analysis of the left-hemisphere patients was an interaction between target field and cued versus uncued rectangle, $F(1, 4) = 25.49$, $p < .01$. The disadvantage for the uncued rectangle versus the cued rectangle was much greater when responding to contralesional field targets (M = 76 ms) than for responding to ipsilesional field targets (no observable cost because the mean difference between invalidly cued targets in the cued and uncued rectangles was −3 ms). The mean costs for the left- and right-hemisphere groups are shown in Figure 5, and the difference between the contralesional and ipsilesional object effects is shown individually for each patient in Figure 6. Note from Figure 6 that all of the left-parietal patients showed a larger object effect for contralesional targets, whereas the difference between the object effects in the two fields clustered around zero for the group of right-parietal patients.

Because of the relatively small number of patients in the left-hemisphere group, performing finer grained analyses of the different cuing effects for the left- and right-hemisphere patients was difficult. However, one marginally significant trend is potentially revealing and warrants mention. The left- and right-hemisphere groups showed very similar costs of invalid cues when the target appeared within the cued rectangle, and a purely spatial shift of attention was required (M = 66 ms for the left-hemisphere group, M = 64 ms for the right). This similarity applied for both target fields ($F < 1$). In contrast, when the target appeared within the uncued rectangle, left-hemisphere patients had greater costs for invalidly cued targets in the contralesional field than did right-hemisphere patients (mean cost of 149 ms for the former and 101 ms for the latter) while showing smaller costs for targets in the uncued rectangle falling in the ipsilesional field (mean cost of 55 ms for left-hemisphere patients, 75 ms for the right-hemisphere patients), $F(1, 11) = 4.54$, $p = .054$. These points are taken up in the General Discussion, as are possible reasons for the differences between our left- and right-hemisphere groups.

There were no significant differences between horizontal and vertical shifts of attention from invalid cues to targets in these analyses. The spatial disengage difficulty with horizontal shifts to an invalidly cued contralesional target replicates the previous findings of Posner, Inhoff, et al. (1987), and the difficulty with vertical shifts within the contralesional field replicates the observations of Baynes et al. (1986). Of course, a lack of power may be masking a real difference between vertical and horizontal shifts.

In summary, the right-hemisphere group showed the spatial disengage deficit reported by previous investigators (Baynes et al., 1986; Morrow & Ratcliff, 1988; Petersen et al., 1989; Posner, Inhoff, et al., 1987; Posner et al., 1984, 1985; Posner, Walker, et al., 1987). That is, there was a larger cost of spatially invalid cuing for contralesional targets than for ipsilesional targets. The object-based component of covert orienting, which we had identified in normal subjects in Experiment 1, was also observed in the patients with right parietal lesions. This cost for shifting attention between objects was equivalent for contralesional and ipsilesional targets in this group, suggesting that, although patients with right parietal lesions are sensitive to object segmentation, damage to the right parietal cortex does not compromise the object-based component, which was normal in both visual fields.

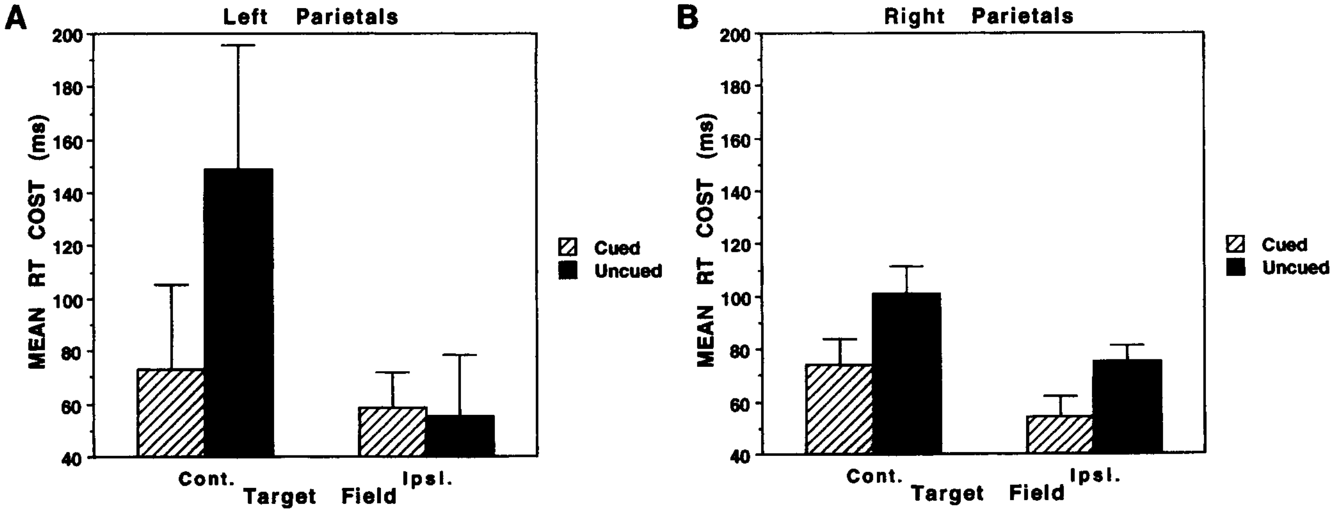

Figure 5. Means of the median costs from invalid cuing (given by invalid-cue reaction time, or RT, minus valid-cue RT) in Experiment 2. Data are shown as a function of the two invalid-cue conditions (i.e., whether the rectangle that contained the invalid target was cued or uncued) and of target field (Cont. = contralesional; Ipsi. = ipsilesional). A: Data for the left-parietal group. The means that were subtracted from invalid-cue RTs to yield the illustrated costs were 468 ms for contralesional targets and 447 ms for ipsilesional targets. B: Data for the right-parietal group. The means that were subtracted from invalid-cue RTs to yield the illustrated costs were 435 ms for contralesional targets and 416 ms for ipsilesional targets.

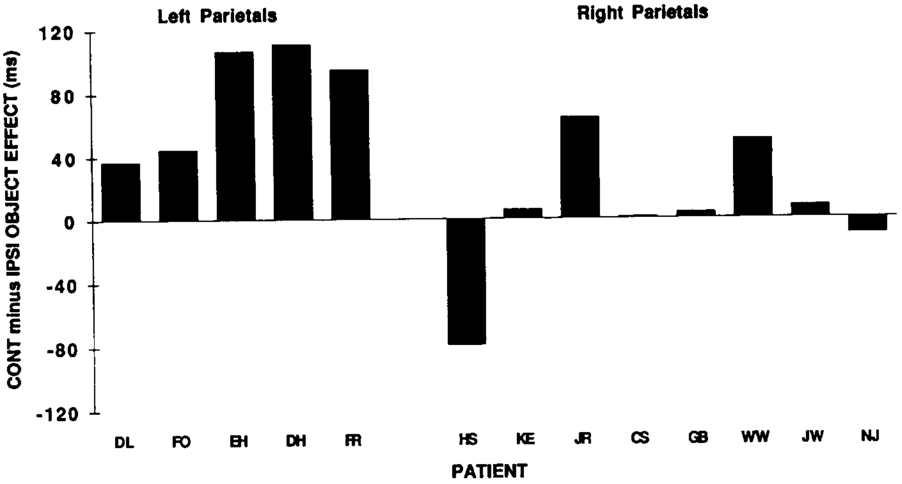

Figure 6. The interaction between the side of the target and the size of the object effect shown separately for each patient in Experiment 2. The ordinate represents the difference between the contralesional (CONT) and ipsilesional (IPSI) object effects, where the object effect for each target field is calculated by the following equation: (uncued rectangle invalid-cue RT) minus (cued rectangle invalid-cue RT). Positive values indicate that the contralesional object effect was greater, and negative values indicate that the ipsilesional object effect was greater. RT = reaction time.

In contrast, the left-parietal group showed an abnormality in the object-based component in addition to the spatial disengage deficit identified by previous researchers. The cost of shifting attention between objects was abnormally large for targets in the contralesional field and abnormally small for targets in the ipsilesional field, which showed no object effect in the left-parietal group.

General Discussion

Our review of previous findings revealed evidence for both space-based and object-based components to visual attention. However, we note that these two components have been identified in very different paradigms. On the basis of previous data, there were few empirical constraints on how the interaction of the space-based and object-based components should be envisaged, and it was even unclear whether they could both apply in the same situation. We also noted that, although there have been advances in relating space-based mechanisms to neural systems, such as Posner et al.'s (1984; Posner, Walker, et al., 1987) three-component (disengage, move, engage) model of spatial orienting, there have been no attempts to relate object-based attention mechanisms to particular neural structures. The present experiments provide a first attempt to address these issues.

We developed a variation of the spatial precuing paradigm to measure both the costs of shifting attention between different loci in the same object and any additional costs of shifting a comparable distance and direction to part of another object. In Experiment 1, we found evidence for both space-based and object-based components to covert visual orienting in normal observers. Invalid cues produced a cost when attention had to be shifted from the cue to another location within the same object, demonstrating a space-based component to attention. However, the costs of invalid cues were significantly larger when attention had to be shifted an equivalent distance and direction to part of another object, demonstrating an object-based component as well.

The demonstration of space-based and object-based limitations within a single stimulus array rules out some conceptions of the relationship between object-based and space-based mechanisms. Vecera and Farah (1992) suggested that purely object-based attentional limitations might arise only when the task requires object-centered representations of shape, whereas purely spatial limitations will be apparent whenever the task can be performed by detection of visual features that are represented in an array format by visual cortex. In Experiment 1, we produced both space-based and object-based limitations in a task that simply required detection of salient luminance increments. Changes in luminance are known to be represented in spatiotopic cortical maps, and our task should therefore show only space-based limitations on Vecera and Farah's hypothesis.

Our second experiment provided the first neuropsychological investigation of the neural structures that compromise the object-based components of visual covert orienting when damaged. The performances of right- and left-parietal patients were examined in the same precuing task that had identified space-based and object-based components of visual attention in normal subjects. Our measure of the spatial component revealed the abnormality that has previously been associated with unilateral parietal injury by other investigators. That is, the parietal patients showed a greater cost of invalid cuing for contralesional targets than for ipsilesional targets—the spatial disengage deficit previously reported by Baynes et al. (1986), Morrow and Ratcliff (1988), and Petersen et al. (1989) and originally observed by Posner et al. (1984; Posner, Inhoff, et al., 1987; Posner, Walker, et al., 1987).

Like the normal subjects, both groups of patients showed an additional cost of invalid cuing when attention had to be shifted between objects as well as between locations. In the right-parietal lesion group, this object-based cost was normal in both visual fields, suggesting that right-parietal damage does not compromise the object-based component measured here. This finding is consistent with previous demonstrations that the distribution of visual attention in right-parietal patients with left neglect is sensitive to object segmentation (Farah et al., 1989; Driver et al., 1992; Driver & Halligan, 1991). The distribution of attention for right-parietal patients in the present study was sensitive to object segmentation, just as for the normal observers in Experiment 1. Indeed, the right-parietal group patients were equally sensitive to the object manipulation in their ipsilesional and contralesional visual fields, suggesting that object segmentation can be normal in both visual fields after right-parietal damage (Driver et al., 1992).

In contrast, the left-parietal patients in our sample showed an abnormal object-based difficulty for contralesional versus ipsilesional targets in addition to the purely spatial disengage deficit. The left-parietal patients were abnormally slow for contralesional targets, which required a shift of attention between objects (see Figure 5). Thus, unlike right-parietal damage, left-parietal lesions were found to produce a pathology in shifting attention between objects. So, in addition to identifying distinct space-based and object-based components to visual covert orienting, our experiments found that the cerebral hemispheres may be differentially specialized for them.

Although showing an exaggerated object effect for targets in the contralesional field, the left-parietal group showed no reliable object effect for ipsilesional targets. At present, we have no detailed explanation for this aspect of the results. However, we note that it is not unusual in neuropsychology to find that the "good" hemisphere can behave abnormally (even supranormally) following damage to the other hemisphere, presumably as a result of competitive interactions between the two hemispheres.

It may seem surprising to find that left-parietal patients have an attentional impairment that is absent in right-parietal patients, because the conventional finding is that attentional deficits such as neglect are more common and severe following right- rather than left-hemisphere lesions (e.g., Ogden, 1987; see Jeannerod, 1987, or I. H. Robertson & Marshall, 1993, for further reviews). However, data from patients with florid, clinical neglect may be misleading in this context. We specifically excluded acute patients with florid neglect from our lesion study because we suspect that the full-blown manifestations of clinical neglect probably reflect a multicomponent syndrome (see I. H. Robertson & Marshall, 1993, for substantial evidence on this point). The multicomponent syndrome likely involves damage to several attentional systems beyond the specific disengage systems examined in the present research (e.g., additional systems involved in eye movements and arousal). In other words, the fact that clinical neglect is usually more severe following right-hemisphere damage may arise because of damage to other right-lateralized systems in addition to the disengage systems examined here, such as the right-hemisphere arousal system postulated by Posner et al. (Posner & Petersen, 1990; Posner, Walker, et al., 1987).

From this multicomponent perspective, a greater understanding of neglect will require fractionation of normal attention mechanisms (and of attentional deficits) into specific component operations. This may be achieved by devising measures for each potential component, as we have attempted here, and then relating each identified component to specific neural structures or networks. This goal may not best be realized by studying groups of patients with clinical syndromes that are potentially heterogenous in their causes. It may be more appropriate to study groups of clinically stable patients selected on the basis of restricted anatomical lesions, as we have attempted here (see L. C. Robertson, Knight, Rafal, & Shimamura, 1993, for a further discussion of these methodological issues).

We now consider various accounts of the differential specialization of left versus right parietal cortex for the object-based component of attention identified by our studies. Some accounts can be dismissed on the basis of the present data. One suggestion might be that the right-parietal patients no longer perceive the elongated rectangles as coherent global objects perhaps because of the perceptual bias toward local features, which is often observed following damage to cortex of the right temporoparietal junction (L. C. Robertson, Lamb, & Knight, 1988; left temporoparietal junction lesions, in contrast, produce a global perceptual bias). This account can be ruled out because our right-parietal patients showed the normal pattern of sensitivity to object segmentation in our task in both visual fields, demonstrating that the rectangles are perceived normally as distinct objects by this group.

Another hypothesis is that both groups of patients perceive the rectangles as global objects but that the distribution of attention across the objects before the onset of the cue differs between the two groups of patients. Perhaps the left-parietal patients tend to attend to whole objects in the fixation display, whereas the right-parietal patients attend to isolated parts of the objects and therefore show less of a difference for between- versus within-object shifts of attention on invalid-cue trials. This might arise if there were different local or global biases in attention for right- versus left-hemisphere patients, analogous to the different patterns of local/global perceptual biases identified by L. C. Robertson et al. (1988). Any account that postulates differences in the distribution of attention for the two groups before the cue can be dismissed, however. Such accounts do not accommodate the finding that the two groups were indistinguishable for within-object shifts of attention (compare the data points for the two groups represented by the white bars in Figure 5).

The most straightforward conclusion from our data is that the left hemisphere is relatively specialized for shifting attention between objects compared with the right hemisphere. Note, however, that this statement does not unambiguously specify which hemisphere is more specialized for representing scenes in terms of distinct objects. The implications of our data for this question depend on how one conceives the interaction of the two hemispheres in controlling the engagement and disengagement of visual attention. We found that damage to the left parietal cortex (but not the right parietal cortex) impaired the disengagement of attention from one object when a move to another was required to detect a contralesional target rather than an ipsilesional target. Impaired attentional disengagement from objects was operationally measured by exaggerated costs from invalid cuing of the rectangle where the target did not appear. This follows the logic Posner et al. established (1984; Posner, Inhoff, et al., 1987; Posner, Walker, et al., 1987), although in our critical conditions the invalid cue specified an inappropriate object as well as an inappropriate location. On Posner et al.'s assumption that exaggerated costs from invalid cues reveal the defective operation of disengage systems, our results suggest that the left hemisphere is specialized for disengaging attention from objects. This suggests that the left hemisphere is more specialized than the right for representing scenes as distinct objects.

However, another perspective leads to the opposite conclusion concerning which hemisphere is specialized for object representation. Kinsbourne (e.g., 1987, 1993) argued that activation of each hemisphere produces a contralateral orienting tendency. Thus, the two hemispheres produce opposing directional "vectors," and the observed orienting response will be the outcome of the competition between them. From this perspective, one hemisphere will act to disengage attention from whatever the opposing hemisphere is engaged on. Thus, our finding that left-parietal damage leads to difficulties in disengaging from objects for contralesional targets implies that the right hemisphere tends to engage attention on objects. The disengage function of one hemisphere would necessarily mirror the engage function of the other hemisphere on Kinsbourne's competition account. Note that if this account of our hemisphere specialization data is correct, the right-hemisphere system, which engages on objects, must be outside the right parietal cortex because we found that patients with right-parietal damage showed normal object-based effects, implying that their attention was normally engaged on objects despite their parietal damage. This agrees with Posner's (1988) separation of disengage and engage functions (contrary to Cohen & Farah, 1991), the disengage function subserved by parietal cortex, and the engage function by the thalamus. The suggestion that the right hemisphere is specialized for engaging attention on objects also agrees with evidence from the visual agnosias (impairments of object perception after brain damage) that suggests that the right hemisphere is normally specialized for segmenting scenes into discrete objects and for providing structural descriptions of each object (e.g., Farah, 1990; McCarthy & Warrington, 1990).

The current findings may also be helpful in understanding the striking simultaneous agnosia seen in patients with Balint's syndrome. Farah (1990) suggested that these patients may have a bilateral dysfunction of the parietal disengage operation suggested by Posner et al. (1984; Posner, Walker et al., 1987). Our results indicate that a left-parietal lesion may add a specific pathology in object-based selection to the spatial deficit created by right-parietal lesions. This formulation could explain why patients with bilateral parietal lesions typically have both object-based difficulties (their simultaneous agnosia) and space-based difficulties (their spatial disorientation).

Interpretation of our results in terms of hemisphere specialization for object representation depends on a greater understanding of how the hemispheres interact in controlling the engagement and disengagement of visual attention for objects and locations. We are currently investigating this question with studies of split-brain patients and with visual-field and event-related potential studies of normal observers using our cuing paradigm. Whatever the resolution of this issue, our findings clearly establish that there are both space-based and object-based components to covert visual covert orienting. These can both be evident within the same detection task. The distinction between object-based and space-based components is further evidenced by the finding that different kinds of brain injury can differentially affect them. Right-parietal damage appears to impair only the space-based component, whereas left-parietal damage appears to impair both the space-based and object-based components.

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