

# Impaired stimulus-driven orienting of attention and preserved goal-directed orienting of attention in unilateral visual neglect

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CHUN R. LUO

Wesleyan University

JEFFREY M. ANDERSON

University of Florida

ALFONSO CARAMAZZA

Harvard University

Neglect patients do not respond to stimuli presented on the side of space contralateral to the side of their brain lesions, indicating deficits to attentional or representational mechanisms. We describe a patient who shows a left neglect in normal reading and line bisection but an intact ability to locate the left end of the stimulus. Further tests showed that his seemingly intact ability to search into the "neglected" side was due to his ability to use local elements of the stimulus as cues in his serial search for the left end. The patient's left neglect was significantly reduced after he located the left end of the stimulus. In contrast, his neglect was not reduced by making the stimulus on the neglected side physically more salient. These results suggest that his neglect is due largely to an impairment of the mechanism mediating automatic, stimulus-driven orienting of attention. In contrast, the controlled goal-directed attentional search is largely preserved and can be used to alleviate neglect.

Unilateral or hemispatial visual neglect is a neuropsychological-behavioral deficit in which patients do not respond to stimuli presented on the side of space contralateral to the side of their brain lesions. Neglect patients exhibit a wide range of behavioral problems. For example, they may eat food only on one side of the plate, draw only one half of a picture, or read only one half of a word. Neglect patients are often unaware of and may deny the existence of these behavioral problems. These patients may also neglect auditory or tactile information presented on one side of space. It appears that left neglect with right brain damage is much more common and severe than right neglect with left brain damage (Caramazza & Hillis, 1990a; De Renzi, 1982; Friedrich, Walk-

er, & Posner, 1985; Mesulam, 1981, 1983; Ogden, 1987; Warrington, 1991).

Despite intensive research in the past decade, the mechanisms underlying unilateral neglect are far from clear. There are several competing explanations of the phenomenon. They can be categorized into two broad categories: representational accounts and attentional accounts. The representational accounts (Bisiach, 1996; Bisiach & Luzzatti, 1978; Caramazza & Hillis, 1990a) attribute unilateral neglect to impairments in processes mediating the computation of different levels of internal representations (see Caramazza & Hillis, 1990a; Marr, 1982, for more details), whereas the attentional accounts (Heilman & Valenstein, 1979; Humphreys & Riddoch, 1993; Kinsbourne, 1987; Posner, Cohen, & Rafal, 1982; Riddoch & Humphreys, 1983) attribute the deficit to impairments in processes modulating the allocation of attentional capacity.

Three different attentional accounts have been proposed. According to Riddoch and Humphreys (1983), neglect occurs because of impaired orienting of attention to stimuli presented contralaterally to the side of current attentional fixation. In contrast, according to Kinsbourne (1987) and Ladavas (1990), neglect occurs because of overly strong orienting of attention to the ipsilateral stimulus, not because of impaired orienting to the contralateral side. Finally, according to Posner and his colleagues (Posner et al., 1982; Posner, Walker, Friedrich, & Rafal, 1984), neglect is caused by a deficit in disengaging attention that has been captured by stimuli presented on the ipsilateral side of space. Humphreys and Riddoch (1993) attempted to integrate these ideas and proposed an attentional network that consists of three modules: stimulus-driven orienting, voluntary (goal-directed) orienting, and attentional engagement. They argued that these modules interact in a mutually inhibitory manner, determining the pattern of neglect.

Because unilateral neglect is a heterogeneous syndrome and each account mentioned here may have its own merit in pinpointing the potential impairment in a particular patient group, the purpose of the present study is not to determine which account can best explain the neglect syndrome in general. Rather, the purpose is to describe the neglect pattern of a brain-damaged patient (P.T.) and to provide more empirical evidence for distinguishing these different accounts of the neglect syndrome.

The focus of this study is on whether unilateral neglect can be alleviated or eliminated by cuing and orienting instructions. This issue is of considerable interest and importance for both theoretical and practical reasons. Theoretically, the clarification of this issue can help us understand the mechanism underlying neglect. For example, if neglect can be eliminated by cuing and orienting instructions, it would indicate

that spatial neglect is caused, at least in part, by an impairment to the orienting mechanism. Practically, the study of the effects of cuing and orienting instructions has implications for the design of training and rehabilitation techniques.

Several studies have investigated the effect of cuing on neglect. For example, Heilman and Valenstein (1979) investigated whether visual neglect in a line bisection task can be alleviated by cuing patients to attend to the neglected side of lines. In their study, a letter was added to each end of the to-be-bisected line. On half of the trials, before bisecting a line, patients were instructed to look to the left end of the line and to report the letter at that end. On the other half of the trials, patients were instructed to look to the right end of the line and to report the letter at that end. Heilman and Valenstein found that cuing had no effect on patients' performance in line bisection and that the amount of neglect was the same regardless of whether patients were asked to report the left or right letter. Because left neglect in a line bisection task was not reduced by ensuring that patients looked to the left end of the line, they concluded that neglect was not caused by a failure to orient to the contralateral side of space.

However, Heilman and Valenstein's (1979) study has some weaknesses. As pointed out by Riddoch and Humphreys (1983), their study did not include appropriate conditions in which there was no cue present at all or there was only one cue present to only one end of the to-be-bisected line. It is possible that Heilman and Valenstein found no effect of a left-side cue because the presence of a concurrent right-side cue interfered with attention being allocated to the left-side cue. Riddoch and Humphreys (1983) conducted two experiments to test this possibility.

In the first experiment, they had four cuing conditions: no-cue, single-left-cue, single-right-cue, and dual-cue (both-left-and-right-cue). Patients were asked to report any digit (cue) they saw before bisecting a line. Using performance in the no-cue condition as a baseline, Riddoch and Humphreys found a marked decrease in neglect in the single-left-cue condition. In contrast, the amount of neglect was increased in the single-right-cue and dual-cue conditions.

In the second experiment, they investigated why patients' performance in the dual-cue condition resembled their performance in the single-right-cue condition by instructing the patients to report either the left cue, right cue, or both left and right cues in the dual-cue condition. Line bisection was not allowed until the required cue had been reported. They found a significant reduction in neglect whenever patients were forced to report the left cue, regardless of whether the right cue was also to be reported. This finding suggested that no effect of cuing

in the dual-cue condition in their Experiment 1 occurred because the patients were not forced to report the left cue and their attention was automatically drawn to the nonneglected side, where the right cue was present.

Riddoch and Humphreys interpreted their findings in terms of impaired stimulus-driven orienting and intact conscious orienting of attention in neglect patients and suggested that cuing and orienting instructions can be used to alleviate the neglect syndrome.

Several other studies (Halligan & Marshall, 1989; Nichelli, Rinaldi, & Cubelli, 1989; Reuter-Lorenz & Posner, 1990) also showed that cuing can be effective in reducing neglect. For example, Halligan and Marshall asked a left neglect patient to bisect a line shown on a computer screen. The patient made her transections by moving a mouse-controlled cursor arrow. The study showed that when the cursor was at the left end of the stimulus line, there was a significant reduction in neglect. More recently, Halligan, Manning, and Marshall (1991) showed that cuing neglect patients to look to the neglected side by placing their hand on the neglected end of lines also reduced neglect in line bisection. They argued that the position of hand induced the patients to orient their attention to the neglected side of space, thus reducing neglect. Similarly, studies using eye patching and movement as cues (Butter & Kirsch, 1992, 1995) also showed reduction in neglect.

Most recently, Ladavas and her colleagues (Ladavas, Carletti, & Gori, 1994; Ladavas, Menghini, & Umiltà, 1994) showed that visual neglect can be reduced by manipulating orienting of attention alone. In their study, goal-directed or internally controlled orienting of attention was tested by presenting central valid cues, whereas stimulus-driven or externally controlled orienting of attention was tested by presenting peripheral invalid cues. They concluded that neglect patients have a deficit in stimulus-driven orienting of attention, in support of the idea that stimulus-driven automatic orienting of attention is more impaired than goal-directed voluntary orienting of attention in neglect patients, and that visual cues can be used to remedy the impairments.

In the present study we investigated the effects of cuing and orienting instructions on a neglect patient's performance in reading and the line bisection task. Very few studies have looked at whether cuing is effective in reducing neglect dyslexia. In one related study, Sieroff (1990) presented a digit before the presentation of word or nonword stimuli as a spatial cue. Stimuli were either centered or presented bilaterally. The patient's task was to read the stimuli and ignore the digit, read the digit and the stimuli, or read the stimulus on the same side as the digit (without reporting the digit) and ignore the other stimulus. Sieroff found that cuing seemed to have a small beneficial effect on

centered nonwords when the digit was to be named. The results for words were not presented.

In addition to investigating the effects of cuing on both reading and line bisection, there is another important difference between our study and most previous studies. In our study we did not add a digit or letter to the original stimulus or position the patient's hand into the neglected side of space as cues; rather, the patient was asked to locate the left end of the stimulus as a way of cuing the patient to orient to the neglected side of space. If this cuing technique is successful in alleviating unilateral visual neglect, it would have more potential use than physically adding cues to a stimulus or positioning patients' limbs on the neglected side of space.

## **CASE REPORT**

### **Medical history**

P.T. is a 54-year-old right-handed man who completed 4 years of college. He worked for a brush company as a purchasing manager until he suffered an acute, massive cerebral ventricular hemorrhage about 2 years before this investigation. He lives at home with his wife. One striking characteristic of this patient is that he exhibits a daily pattern of cycling from "good" (little neglect) to "bad" (severe neglect) days. The data we present were collected on the "bad" days.

When P.T. was first admitted to the hospital, an initial angiogram revealed an arteriovenous malformation (AVM) located in the right temporal horn and the temporal lobe. He then had a right temporoparietal craniotomy for resection of the AVM. Postoperatively there was some seizure activity, but this resolved quickly. A later magnetic resonance imaging (MRI) scan showed that there were postoperative changes in a shunt tube tract through the corpus callosum and that there was low signal in the region of the right temporal horn of the lateral ventricle, representing degradation products. The most recent computed tomography scan showed low attenuation in portions of the right temporal and frontal lobes. A more recent MRI on July 13, 1995 largely reproduced these results.

### **Clinical evaluation of cognitive abilities**

A series of tests showed that P.T.'s speech was normal and his comprehension was good. He showed no trouble in single word or simple sentence repetition. He named color patches correctly. In a picture-naming task, he correctly named 240 of 250 Snodgrass and Vanderwart

(1980) pictures. In contrast, his reproduction of line-drawing objects lacked details and showed omissions and distortions on the left side. Figure 1 shows P.T.'s attempt to copy a house, and Figure 2 shows his attempt to copy a clock.

In a line cancellation task with 48 lines on a page, he crossed only 14 lines on the far right side of the page. Similarly, in a horizontal line bisection task, his attempt to bisect a 200-mm line deviated to the right on an average of 40 mm. P.T.'s left neglect was also evidenced by his reading performance. In reading single words, he often read only from the right half of the words (e.g., *WOOD* became *FOOD*, *SPOTLIGHT* became *LIGHT*). Similarly, in reading sentences he neglected the left part of a sentence. In addition, on the Borb test, which asks subjects to judge whether a line-drawing picture depicts a real animal or an unreal animal (e.g., a cat's head being attached to a dog's body), P.T. was unable to tell real from unreal animals when the deciding features were on the left side of the picture.



Figure 1. P.T.'s attempt to copy a house

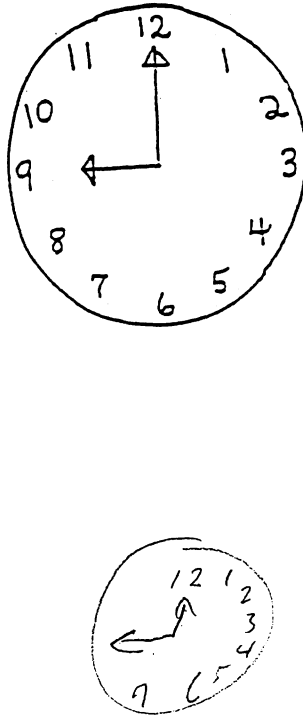


Figure 2. P.T.'s attempt to copy a clock

### EXPERIMENT 1

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This experiment had two purposes. The first was to investigate whether P.T. was able to locate the left end of a word despite his left neglect in normal reading. In other words, we wanted to investigate whether he could search into the neglected side of space when he was given an orienting instruction that induces a serial attentional search. As already noted, P.T. often makes errors in reading the left part of a word, indicating that the initial letters are seemingly undetected by the word recognition system. The question of interest is whether P.T. is able to tell where the first letter of the word starts when he is explicitly asked to do so.

The difference between reading a word and locating the left end of the word is that in the former the unit of attention is the whole word, whereas in the latter the unit of attention is individual letters. A dissociation between an inability to perceive the left side of a global object and an intact ability to perceive local elements of neglected information would be interesting because it would suggest that neglect might

be alleviated if, before reading, neglect patients are cued or instructed to use the local elements of the object to guide their attentional search. The second purpose of this experiment was therefore to investigate whether P.T.'s left neglect in reading could be alleviated after he was asked to locate the left end of a word.

## METHOD

In this experiment P.T. was asked to read 60 words with word length ranging from four to eight letters, matched for word frequency. There were 12 trials for each word length under two test conditions. In the first condition P.T. was asked to read and spell a word centered on a page and then mark the left end of the word with a pencil. In the second condition he was asked to mark the left end of a word with a pencil and then read and spell it. Each word was printed in uppercase Palatino typeface in 14-point size and centered on a piece of white paper. Each page was presented in front of the patient, centered at the midline of his body. Half of the 60 words were tested in the first condition, and the other half were tested in the second condition. To control the sequence effect, the 60 trials were divided into four blocks and presented in the ABBA order. Before the experiment, the patient was given 10 practice trials to get familiarized with the task. There were 5 practice trials in each of the two test conditions in the ABBA order.

### Scoring

On most trials, P.T. was able to read aloud and spell presented words. In those cases, his readings were the responses to be analyzed because reading and spelling were almost always consistent with each other. On a few trials, P.T. was not able to read aloud but was encouraged to spell the letter strings he saw. For example, he was not able to read the word *QUESTION*, but responded *ESTION* when he was asked to spell it. In such cases, his spellings were the responses to be analyzed. P.T.'s reading/spelling performance (error rate) was obtained using the following scoring procedure. First, each letter of a word was assigned an ordinal number indicating its position from the left end of the letter string. Then the response from P.T. was compared to the target word. A missing or incorrect letter in place of a letter in the target word was scored as a 1-point error in that position. P.T.'s performance in marking the left end of a word (marking error) was measured by the number of letters missed in marking.

## RESULTS

P.T. made very few errors in marking the beginning of words. When marking first, his marking error was 0, 8%, 17%, 8%, and 17% for five word lengths. When reading first, his marking error was 0, 0, 0, 8%, and 0 for five word lengths. His performance in locating the left end of a word thus showed little signs of left neglect.

P.T.'s reading/spelling, however, showed left neglect. For example, he responded *MAGIC* for *TRAGIC*, *ABLE* for *TROUBLE*, and *FOUNTAIN* for *MOUNTAIN*. Table 1 shows P.T.'s reading/spelling performance as a function of word length before and after he was asked to mark the left end of the word. Two results are of interest. First, before being asked to locate the left end of the word, P.T.'s reading performance was a decreasing function of letter position; reading errors occurred mostly on the left half of a word, indicating a left neglect. Second, in contrast to his performance in normal reading, reading performance improved drastically, and the left neglect was basically eliminated after the patient attempted to mark the beginning of words.

The results of this experiment indicate that despite his left neglect in normal reading, P.T. was able to search into the neglected field when the task induced a serial search that guides attention from right to left. The findings suggest that neglect can be drastically reduced or eliminated by cuing and orienting instructions that encourage or force neglect patients to search into the neglected side of space.

Table 1. P.T.'s percentage of reading errors at each letter position before and after marking the beginning of words in Experiment 1

Word length	Letter position (from left)							
	1	2	3	4	5	6	7	8
Reading before marking								
4	50	50	17	0				
5	50	33	0	0	0			
6	50	50	17	0	0			
7	100	83	33	33	17	0	0	
8	50	33	17	17	17	0	0	0
Reading after marking								
4	0	0	0	0				
5	33	0	0	0	0			
6	17	17	0	0	0	0		
7	20	0	0	33	0	0	0	
8	17	0	0	0	0	0	0	0

## EXPERIMENT 2

The purpose of this experiment was to investigate whether the same pattern of results as found in Experiment 1 would emerge when the patient was asked to perform a line bisection task. Specifically, we examined whether P.T. was able to locate correctly the left end of a line despite his left neglect in normal line bisection. Also importantly, we

examined whether his left neglect in line bisection could be alleviated or eliminated after he had attempted to locate the left end of the line.

## METHOD

In this experiment P.T. was asked to bisect 72 lines, with line lengths of 10, 20, 40, 80, 120, and 160 mm. There were 12 trials for each line length under two test conditions. In the first condition P.T. was asked to bisect a line centered on a page and then to mark its left end with a pencil. In the second condition he was asked to mark the left end of a line with a pencil and then to bisect it. Half of 72 lines were tested in the first condition, and the other half were tested in the second condition. To control the sequence effect, the 72 trials were divided into four blocks and presented in the ABBA order. Before the experiment the patient was given 12 practice trials, 6 trials in each of the two test conditions in the ABBA order.

## RESULTS

P.T. was remarkably accurate in locating the left end of a line. He made marking errors (displaced to the right) in only 2 of 72 trials, indicating his almost intact ability to search into the apparently neglected left side. Table 2 shows P.T.'s performance in line bisection before and after marking the left end of a line.

Table 2. P.T.'s performance on a horizontal line bisection task before and after marking the left end of a line in Experiment 2

Line length (mm)	Deviation from midpoint (mm)	
	Mean	SD
Line bisection before marking		
10	- 1.1	0.74
20	+ 2.6	1.41
40	+ 9.1	4.20
80	+20.5	10.66
120	+31.9	4.96
160	+22.1	10.99
Line bisection after marking		
10	- 0.2	0.68
20	- 0.1	0.92
40	+ 0.3	1.72
80	- 4.7	5.09
120	- 2.9	7.50
160	-13.3	9.53

*Note.* + indicates displacement to the right of the true midpoint, and - indicates the left of the true midpoint.

The results in the line bisection task replicate those found in the reading task in Experiment 1. First, in the normal line bisection task P.T. showed an overall bias toward the right of the midpoint in line bisection except for very short lines (10 mm), indicating a left neglect. Second, in contrast to his performance in normal line bisection, his left neglect in line bisection was basically eliminated after he had attempted to mark the left end of the line. In fact, there appeared to be a small right neglect with very long lines.

To summarize, P.T.'s performance on the line bisection task was consistent with what was found in reading. Despite his left neglect in normal reading and line bisection, he was able to respond to the seemingly neglected information by correctly locating the left end of a stimulus. Importantly, there was a marked reduction in his left neglect after he was asked to locate the left end of the stimulus. The findings demonstrate an important dissociation between unilateral neglect in normal reading and line bisection and an intact ability to search into the neglected side of space when the task induced a serial search strategy.

P.T.'s preserved ability to search into the neglected side of space was also evidenced by the results of another test, which required him to copy a straight line on a piece of paper. He showed no signs of neglect in this task and was able to copy lines of varying length with good accuracy. Specifically, for lines of 10, 20, 40, 80, 120, and 160 mm, on an average he drew lines of 11.0, 17.0, 55.0, 80.3, 120.5, and 163.5 mm, respectively.

Taken together, these findings indicate that despite his left neglect, P.T. could search into the neglected part of a stimulus when the task required him to perform a serial search. This dissociation was related to the difference in the focus of attention. Although P.T.'s left neglect was evident when the focus of his attention was on the global object, his left neglect was alleviated or eliminated when the focus of his attention was on the local elements of the stimulus. Presumably, when his attention was focused on the local elements, each element served as a cue to its neighboring elements. In the case of locating the left end of a word, each right letter was a cue to its left letter. Attention thus flowed from one letter to another. Similarly, in the case of marking the left end of a line, his attention tracked the line from right to left. In short, if a task induces the movement of attention from right to left, visual neglect can be alleviated.

### **EXPERIMENT 3**

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If it is the case that when P.T. is asked to locate the left end of a stimulus, he uses local elements of the stimulus as cues to guide his search into the neglected side of space, then it can be predicted that his per-

formance in reading and locating the beginning of a word will decline as letter spacing increases. This is a reasonable prediction because when letter spacing is increased, the effectiveness of local elements (e.g., letters) of a stimulus (e.g., word) serving as cues to one another should be reduced. The purpose of this experiment was to test this prediction.

In this experiment, 150 words were used as stimuli. Word length was varied from 4 to 8. Each word was printed in uppercase Palatino typeface in 14-point size and centered on a piece of white paper. Spacing was 0 (no space between letters), 1 (one space), or 2 (two spaces). The patient was asked first to mark the beginning of a word and then to read it aloud. Table 3 shows P.T.'s performance in locating the left end of a word as a function of word length and letter spacing. Table 4 shows his reading/spelling performance as a function of word length and letter spacing. It is clear that marking errors and reading errors are both an increasing function of letter spacing. The fact that P.T.'s marking and reading performance depends on letter spacing provides support for the notion that P.T.'s seemingly intact ability to locate the beginning of a word or a line results from his preserved ability to use local cues to guide his attentional search.

Table 3. P.T.'s errors (number of letters missed) in locating the left end of a word as a function of word length and letter spacing in Experiment 3

Spacing	Word length				
	4	5	6	7	8
0	0.00	0.00	0.00	0.15	0.25
1	0.10	0.40	0.45	1.20	1.45
2	0.35	0.55	1.40	1.60	2.85

#### EXPERIMENT 4

The results of Experiments 1–3 indicate that P.T. could search into the neglected side of space when there were local cues that could be used to guide serial search. The purpose of Experiment 4 was to investigate whether a salient feature in stimuli such as a colored first letter in a word would be sufficient to attract the patient's attention to the left side of space and thus reduce his left neglect.

In this experiment P.T. was again asked to read and then spell words. There were two variables. The first was the number of words on a line. There were either one or two words on a piece of paper. When there was one word, it was centered on a page. When there were two words, one was shown to the left of the center and one was to the right. The

Table 4. P.T.'s percentage of reading errors at each letter position as a function of word length and letter spacing (reading after marking the beginning) in Experiment 3

Word length/ spacing	Letter position (from left)							
	1	2	3	4	5	6	7	8
0	10	0	0	0				
4 1	30	0	0	0				
2	40	0	0	0				
0	10	0	0	0	0			
5 1	30	10	0	0	0			
2	30	30	0	0	0			
0	20	20	0	0	0	0		
6 1	40	30	10	0	0	0		
2	70	50	30	0	0	0		
0	10	0	0	0	0	0	0	
7 1	30	20	10	0	0	0	0	
2	80	60	20	20	0	0	0	
0	20	20	0	0	0	0	0	0
8 1	40	40	20	20	0	0	0	0
2	80	80	80	60	0	0	0	0

distance between the center of each word to the center of a page was approximately 25 mm. Again, each word was printed in uppercase Palatino typeface in 14-point size. All words had eight letters, with an average frequency of 21.3 per million,  $SD = 2.27$ .

The second variable was whether the first and last letters of the words were colored. There were three conditions: Both the first and last letters of the word were colored red, the first letter of the word was colored red, or none of the letters was colored (all in black). There were 8 trials in each condition, resulting in a total of 48 experimental trials ( $2 \times 3 \times 8$ ). All trials were intermixed and presented in a random order. Before the experiment the patient was given eight practice trials, covering all conditions in random order.

P.T. was tested in two sessions using two different sets of words. In the first session, the patient was not told of the possible existence of colored letters. In the second session the patient was told that some letters might be colored red and that his task was to search for the red letters before reading the word.

Tables 5 and 6 show P.T.'s reading performance before and after being asked to search for red letters, respectively. There are several results of interest. First, when P.T. was not asked to search for red letters in a word,

Table 5. Percentage of reading errors when P.T. was not told of the possible existence of red letters in Experiment 4

Condition	Letter position (from left)							
	1	2	3	4	5	6	7	8
One word, centered								
First and last								
letter colored	75	75	38	13	0	13	0	0
First letter								
colored	75	75	63	63	25	0	0	0
Noncolored	75	63	50	25	0	0	0	0
Two words, left word								
First and last								
letter colored	100	100	100	100	75	75	75	75
First letter								
colored	100	100	100	100	88	75	75	75
Noncolored	100	88	88	88	75	75	75	75
Two words, right word								
First and last								
letter colored	50	25	13	0	0	0	0	0
First letter								
colored	50	50	25	13	0	0	0	0
Noncolored	38	25	0	0	0	0	0	0

*Note.* In each trial there was one word (centered) or two (one left, one right).

he showed the standard left neglect patterns and it made no significant difference whether or how many letters of the word were colored red. Second, when two words were presented (one to the left and one to the right), the left word was almost always undetected by P.T., whereas the right word was read better than a single centered word. Again, however, coloring the first and the last letter of a word had no significant effect on P.T.'s reading performance. Third, after P.T. was asked to search for red letters in a word, his neglect in reading was drastically reduced. However, this did not seem to apply to the left word when there was a right word shown concurrently in the display.

Table 7 shows P.T.'s performance in detecting red letters in a word. First consider the condition in which only one word was presented. When both the first and last letters of the word were colored, P.T. was perfect in detecting the last letter but never detected the first letter, indicating his rightward bias in orienting of attention. When only the first letter was colored, however, P.T. was very good at detecting it, again indicating that he was capable of searching into the neglected side when the task induced a leftward serial search.

Table 6. Percentage of reading errors after P.T. was asked to search for red letters in Experiment 4

Condition	Letter position (from left)							
	1	2	3	4	5	6	7	8
One word, centered								
First and last letter colored	0	0	0	0	0	0	0	0
First letter colored	0	0	0	0	0	0	0	0
Noncolored	0	0	0	0	0	0	0	0
Two words, left word								
First and last letter colored	100	100	87.5	87.5	87.5	87.5	87.5	87.5
First letter colored	100	87.5	87.5	87.5	87.5	87.5	87.5	87.5
Noncolored	100	100	100	100	100	100	100	100
Two words, right word								
First and last letter colored	0	12.5	12.5	0	0	0	0	0
First letter colored	0	0	12.5	12.5	0	0	0	0
Noncolored	0	0	0	0	0	0	0	0

*Note.* In each trial there was one word (centered) or two (one left, one right).

Next consider the condition in which two words were presented (one to the left and one to the right). P.T. did very poorly at detecting red letters in the left word (presented in the neglected side) regardless of whether one or two letters were colored. In contrast, his performance in detecting red letters in the right word was much better. When both the first and last letters of the word were colored, P.T. was perfect in detecting the last letter, but he missed the first letter 50% of the time. This result indicates his rightward bias in orienting of attention even in the nonneglected field. When only the first letter was colored, however, P.T. was very good at detecting it, once again indicating that he was capable of performing a leftward serial search when the task required him to do so.

In summary, the results of this experiment indicate that P.T.'s left neglect could not be reduced simply by making information on the neglected side of space more salient. However, his left neglect could be reduced by inducing a serial search strategy that can use local elements of stimuli as cues.

Table 7. Percentage of detecting colored letters in Experiment 4

Condition	Letter position	
	First letter	Last letter
One word, centered		
First and last letter colored	0	100
First letter colored	87.5	—
Two words, left word		
First and last letter colored	0	12.5
First letter colored	0	—
Two words, right word		
First and last letter colored	50	100
First letter colored	87.5	—

*Note.* In each trial there was one word (centered) or two (one left, one right).

## GENERAL DISCUSSION

In the present study we investigated whether unilateral visual neglect can be alleviated by cuing and orienting instructions. We showed that despite his left neglect in normal reading and line bisection, P.T. was able to locate the left end of a word or a line with good accuracy. This finding demonstrates a dissociation between a left neglect in normal reading and line bisection and a largely preserved ability to search into the neglected side of space when the patient was given appropriate orienting instructions. Importantly, we showed that P.T.'s left neglect in reading and line bisection was significantly reduced or eliminated after he was instructed to locate the left end of the stimulus. The findings from this study have important implications for theories of attention in general and theories of unilateral neglect in particular.

Most theories of attention (Humphreys & Riddoch, 1993; Posner & Boies, 1971; Schneider & Shiffrin, 1977; Treisman & Gelade, 1980) propose two interactive components mediating the orienting of attention: an automatic, stimulus-driven component and a consciously controlled, goal-directed component. A dissociation between P.T.'s left neglect and his preserved ability to search into the neglected side of space lends support to this distinction. It can be argued that P.T.'s left neglect in normal reading and line bisection was caused by an impairment to the mechanism mediating stimulus-driven orienting of attention. The fact that coloring the first letter of a word had no effect on P.T.'s performance supports this notion. In normality, objects in different areas of the visual space can attract observers' attention in proportion to the saliency of their physical features and characteristics. A unique color

almost always leads to the pop-out effect (immediate attentional capture by the stimulus).

P.T.'s impairment in stimulus-driven orienting of attention was also evidenced by the finding that his reading and spelling performance was not affected by adding pseudo-prefixes to the word. In one test, we added either 0, 2, 4, or 6 Xs to the left end of a word that was centered on a page. We tested 104 eight-letter words, and P.T.'s reading performance remained constant across the four conditions of pseudo-prefixing. Specifically, the number of letters read correctly by P.T. was 6.3, 5.2, 6.4, and 5.9 for 0, 2, 4, and 6 Xs, respectively. The finding of no effect of coloring and pseudo-prefixing indicates P.T.'s impairment in automatic, stimulus-driven orienting of attention.

In contrast, P.T. seemed to have preserved ability to perform controlled and goal-directed orienting of attention when given appropriate cues and orienting instructions. This was evidenced by his ability to correctly locate the left end of the stimulus and the fact that his left neglect could be significantly reduced after he was asked to locate the left end of the stimulus. His largely preserved ability to perform goal-directed search was also evidenced by his ability to detect a single red letter in a word on the neglected side of space when he was instructed to do so.

The results of the present study are also useful for clarifying three alternative attentional accounts of neglect discussed earlier. All these accounts attribute neglect to a damage to the orienting mechanism. However, in light of this and other related studies (Ladavas, Carletti, et al., 1994; Ladavas, Menghini, et al., 1994), it seems necessary to specify what component of the orienting mechanism—the automatic, stimulus-driven component or the controlled, goal-directed component—is impaired in the neglect patients. Let us consider each of the three accounts more closely. According to the first account (Riddoch & Humphreys, 1983), neglect occurs because of impaired orienting of attention to stimuli presented contralaterally to the side of current attentional fixation. Our demonstration that P.T. could search into the neglected side when given cuing and orienting instructions indicates that it is the automatic, stimulus-driven component of the orienting mechanism that is impaired in visual neglect. In other words, stimulus features on the neglected side cannot capture attention as effectively as they used to. According to the second account (Kinsbourne, 1987; Ladavas, 1990), neglect occurs because of overly strong orienting of attention to the ipsilateral stimulus, not because of impaired orienting to the contralateral side. Our results do not seem to support this proposal. It appears that attention is oriented toward the ipsilateral side of space because of an impaired ability to automatically orient toward the contralateral side, not an increased abil-

ity to orient automatically toward the ipsilateral side of space. Finally, according to the third account (Posner et al., 1982, 1984), neglect is caused by a deficit in disengaging attention that has been captured by stimuli presented on the ipsilateral side of space. This account posits the deficit primarily at the voluntary, goal-directed component of the orienting mechanism; patients cannot voluntarily shift attention to the neglected side when it is already oriented toward the ipsilateral side. Our results do not seem to support this idea. We have shown that P.T.'s neglect was caused by a deficit in automatic, stimulus-driven orienting of attention to the contralateral side of space and that his controlled, voluntary orienting of attention seemed to be largely intact.

However, it is also important to note that P.T.'s goal-directed voluntary orienting of attention was not completely intact. His attention could be directed only in conjunction with the presence of local cues. This was evidenced by the fact that P.T.'s performance in locating the left end of the word depended on letter spacing. His performance declined as letter spacing increased, indicating that his goal-directed orienting of attention could be performed only with the help of local cues. This conclusion is also supported by the fact that P.T. could not detect the presence of a red letter in a left word when another right word was also present concurrently. Apparently, he could not perform goal-directed attentional search without the guidance of local cues. This partly answers the puzzling question of why it takes outside influences (cuing and orienting instructions) to make the patient do what he is capable of doing. More generally, this is probably related to the fact that neglect patients also have some impairment in conscious awareness and general knowledge of the world, evidenced by their inability to recognize that the clock is incompletely drawn and that the letter strings they produce are nonwords.

On the other hand, the present study does show that unilateral visual neglect can be alleviated when patients are given appropriate cues and orienting instructions. This has important implications for the design of training and rehabilitation techniques aimed at facilitating neglect patients' recovery. The remedy of visual neglect should incorporate procedures that make good use of patients' existing ability in goal-directed orientation and give them instructions that induce them to use local cues to help them reorient their attention to the neglect side of space.

Finally, our assertion that P.T.'s neglect was caused by an impairment to the automatic, stimulus-driven component of the orienting mechanism does not imply that all visual neglect has the same underlying mechanism. In fact, some neglect patients show deficit that cannot be attributed to impairment in the attentional system. For example, some

left neglect patients may fail to describe from memory the salient features on the left side of a familiar room or a building (Bisiach & Luzzatti, 1978). They may also fail to discriminate two objects moving behind the vertical slit of a screen when the critical feature is located on the left side (Bisiach, Luzzatti, & Perani, 1979). More recently, Caramazza and Hillis (1990a, 1990b) reported a patient who neglected the right side of a word regardless of whether the letters of the word were presented horizontally, vertically, or in the form of a mirror image. These cases strongly indicate that there may be another category of neglect in which the disorder is at the cognitive level and that the neglect is caused by a breakdown in constructing a mental representation of stimuli.

### Note

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Correspondence concerning this article should be addressed to Chun R. Luo, Department of Psychology, Wesleyan University, Middletown, CT 06459. E-mail: cluo@wesleyan.edu. Received for publication December 20, 1996; revision received May 4, 1997.

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