Journal of the International Neuropsychological Society (1996), 2, 404–411.
Copyright © 1996 INS. Published by Cambridge University Press. Printed in the USA.

Effects of left-sided movements on line bisection in unilateral neglect

KEH-CHUNG LIN,[1] SHARON A. CERMAK,[1] MARCEL KINSBOURNE,[2] AND CATHERINE A. TROMBLY[1]
[1]Department of Occupational Therapy, Boston University, Boston, MA 02215
[2]Center for Cognitive Studies, Tufts University, Medford, MA 02155
(RECEIVED June 28, 1995; ACCEPTED October 3, 1995)

Abstract

Thirteen patients with left neglect performed line bisection under four conditions: no cue, visual cueing involving the report of a digit placed at the left end of the line, circling the left-end digit, and digit circling plus tracing of the line with the right index finger from its left end to its midpoint before bisection. Digit circling plus finger tracing was unequivocally more effective in reducing left neglect than digit circling alone, which was in turn more effective than visual cueing; indeed, digit circling with tracing completely abolished the rightward bisection bias. Thus continuously directing visuomotor control to the left side of the line (even with the right hand) until bisection is performed reduces neglect more than only requiring patients to attend to left-sided visual cues. The facilitatory effects of the cueing procedures may reflect their differential efficacy in constraining as well as attracting attention and action to the left part of the target line. These findings have implications for neglect rehabilitation. (*JINS*, 1996, 2, 404–411.)

Keywords: Stroke, Hemi-inattention, Cueing, Rehabilitation

INTRODUCTION

Right brain-damaged patients who show left neglect typically bisect a horizontal line to the right of true center (Bisiach et al.,1976, 1983; Schenkenberg et al., 1980). The line bisection task provides a useful index for research on how neglect may be corrected by experimentally manipulating task demands or stimulus parameters. This study investigated the relative effects of various cueing procedures on unilateral neglect as evidenced in line bisection.

Previous research (e.g., Heilman & Valenstein, 1979; Lin, 1993; Nichelli & Rinaldi, 1989; Riddoch & Humphreys, 1983) has demonstrated the effect of visual cueing on line bisection by patients with unilateral neglect. Unquestionably, left-sided cues reduce and right-sided cues aggravate the rightward bisection bias. Another line of research (Halligan & Marshall, 1989a, 1989b; Reuter-Lorenz & Posner, 1990; Samuelsson, 1990) using the line bisection task has examined the effect of direction of scanning on performance. These latter reports have shown that cueing the patient to scan left-to-right helps compensate for neglect.

Receiving growing attention are studies that take a theory-based approach to the remediation of neglect. The attentional theory of unilateral neglect (Kinsbourne, 1970, 1987, 1993) proposes that hemispheric imbalance of orientational tendencies underlies unilateral neglect and that this imbalance, and hence the extent of neglect, may be manipulable by behavioral means. The contralesional movement is one such manipulation.

Neglect Treatment Based on the Contralesional Movement Paradigm

Contralesional limb use reduces neglect in manual pointing (Joanette & Brouchon, 1984; Joanette et al., 1986) and line bisection and cancellation tasks (Halligan & Marshall, 1989c; Halligan et al., 1991; Robertson & North, 1992, 1993; Robertson et al., 1992). How this comes about is still controversial.

Halligan and colleagues (1989c, 1991) and Joanette and colleagues (1984, 1986) agree that left neglect is more

Reprint requests to: Keh-chung Lin, Department of Occupational Therapy, Boston University, 635 Commonwealth Avenue, Boston, MA 02215.

attenuated when the left hand rather than the right hand performs the bisection. While the Joanette group involves differential hemispheric activation through active motor responses by the contralesional hand, the Halligan group favors "spatio-motor cueing" as the mechanism of improvement. Observing that line bisection performance could be modified by changing the starting position of the patient's hand when bisecting lines (i.e., there was less benefit from using the left hand when it was crossed to the right of the lines to be bisected), Halligan and colleagues suggested that hand use on the left acts as a cue that enhances attention to the left side.

Robertson and North (1992) and Robertson et al. (1992) reported diminished neglect on the cancellation test (performed by the right hand) when intermittent contralesional hand movement was required. This effect still existed, both in line bisection and on reading (Robertson & North, 1994), even when the left-hand movement was masked but not when the hand was passively displaced (Robertson & North, 1993). Consistent with the findings of Halligan et al. (1991), crossing the left hand to the right side of the display reduced the effect of left-hand movement. The finding that movements out of the patients' sight modified neglect supports the role of the contralesional limb movement itself as distinct from the visuo-sensory cueing that results from it in mediating the neglect-reducing effects.

Contralesional-hand-based therapy may not be feasible with hemiplegic patients, but the ipsilesional hand can still be used. Although the right hand is controlled by the left hemisphere, and vice versa, each hemisphere also mediates contralaterally directed behavior, regardless of which limb is being used (Heilman & Valenstein, 1979; Kinsbourne, 1970). Contralesionally directed movements of the right hand may, accordingly, lead to an intentional activation of the right hemisphere. In a pilot study by the present authors, verbal report of a digit placed at the left end of a line (i.e., visual cueing) improved bisection, but the bisection bias was further reduced when the patients also directed the right hand leftward to circle the digit, and then traced the to-be-bisected line with the index finger from the left end of the line toward its apparent midpoint before bisecting it (i.e., visuomotor cueing). According to a recent report (Mattingley et al., 1993), contralesionally directed motor acts by the right hand, even in the absence of visible lateralized cues, reduced left neglect in line bisection.

Extending previous research reviewed above, the present investigation explores the relative efficacy in reducing left neglect in line bisection of visual cueing, circling, and circling plus tracing. Intentional theory would predict that tracing, from left to right, would counteract the benefit of the left cueing and circling. Attentional theory would predict that the more effectively attention is constrained to the left extent of the line, the more the bisection bias would be reduced. If so, circling plus tracing would be more effective than circling alone, which in turn would be more effective than visual cueing alone.

METHODS

Subjects

The subjects were 13 right-handed Taiwanese patients with unilateral right brain lesions as evidenced on computed tomography (CT) scans and clinical examination. Upon admission to the study, these subjects had left hemiplegia and sensory impairments, and each one was receiving rehabilitation programs in one of six hospitals in Taiwan. There were 12 males and 1 female, ranging in age from 41 to 66 years (mean age = 57.5, *SD* = 7.5). The duration postonset ranged from 3.3 to 28.6 weeks (mean = 11.5, *SD* = 8.7). All the subjects were right-handed by self-report. Left neglect was diagnosed by means of the following tests: the Random Chinese Word Cancellation Test (Chen Sea et al., 1993), a random shape cancellation test (Weintraub & Mesulam, 1985), a line bisection test (Lin, 1993), and the spontaneous and copied drawing tests. Eleven subjects had left visual field defects, shown on confrontation testing. Demographic and clinical characteristics of the subjects are presented in Table 1.

On the cancellation tests, patients with neglect typically overlook several targets on the contralesional side of the test sheet, although a smaller number of omissions may also be found on the ipsilesional side. Based on the performance of normal Taiwanese on the Random Chinese Word Cancellation Test, Chen Sea et al. (1993) recommended the following diagnostic criteria for unilateral neglect: (1) five or more omissions on the test, and (2) a difference in number of omissions between the left and the right half page equal to or greater than three.

Normative performance by neurologically intact Taiwanese subjects provided reference data for the random shape cancellation test (unpublished observations) and the line bisection test (Lin, 1993). For the present study, left neglect was considered present on the random shape cancellation test if there were eight or more omissions across the test page and if the difference in number of omissions between the left and the right half page reached three or more. The line bisection test consisted of three horizontal black lines of 12, 18, and 24 cm in length, each of which was presented separately on a sheet of B4 (36 × 25.5 cm) paper. Left neglect on the test was indicated by an average bias index (see Procedures) of .055 or more; that is, an average displacement of the marks to the right of the true center by 5.5% or more of the half-length of the lines. These criteria for identifying left neglect were based on the normal limits derived from performance of control subjects.

On the spontaneous drawing test, the patients were required to draw a clock with the time set at 10 after 11 (Kaplan, 1988). On the copied drawing test, the patients were required to copy a clock with the time set at 10 after 11, a Necker cube, and a cross. Unilateral neglect on the spontaneous and copied drawing tests is characterized by omission or distortion of the left portion of the figure and positioning of the figure on the right side of the page.

Table 1. Demographic and clinical data for the individual subjects

Subject	Age	Sex	No. of weeks postonset	Site of lesion	Type of lesion	Bias index[a] on line bisection	No. of omissions on word cancellation[b]	No. of omissions on shape cancellation[c]
1	64	M	28.6	Frontal, temporal, and parietal	Infarction	.32	38	45
2	54	M	24.9	Thalamus	Hemorrhage	.67	48	45
3	63	M	7.0	Frontal, temporal, and parietal	Infarction	.36	NA	45
4	65	M	20.4	Frontal and parietal	Infarction	.59	NA	56
5	41	F	5.9[d]	ACA, MCA bifurcation	Aneurysm	.38	12	10
6	56	M	7.9	Internal capsule, anterior limb; pons; lentiform nucleus	Infarction	.25	42	43
7	66	M	8.3	Occipital	Infarction	.23	9	7
8	55	M	3.3	Putamen	Hemorrhage	.45	50	39
9	60	M	6.0	Putamen	Hemorrhage	.12	53	47
10	52	M	6.1	Frontal, temporal, and parietal	Infarction	.19	26	22
11	52	M	6.3	Putamen	Hemorrhage	.29	6	10
12	67	M	20.4	Temporal, parietal, and basal ganglia	Infarction	.32	31	41
13	52	M	4.3	Paraventricular white matter, deep white matter, and inferior occipital	Infarction	.45	48	49

NA = not available; MCA = middle cerebral artery; ACA = anterior cerebral artery. Left visual field defects were present in most of the subjects (except Subject 5 and Subject 10).
[a]Indicates the degree of bisection displacement from the true center. The index can range from −1 to 1, with 0 representing no bias toward either side. A positive value indicates a rightward bias. See text for its computation.
[b]The Random Chinese Word Cancellation Test (Chen Sea et al., 1993). Numbers of target stimuli = 60.
[c]The random shape cancellation test (Weintraub & Mesulam, 1985). Numbers of target stimuli = 60.
[d]Time postneurological intervention.

Materials

Horizontal black lines were drawn, one per page, on sheets of white B4 (36 x 25.5 cm) paper. Each line was approximately 1 mm wide and centered on the page. Line lengths of 12, 18, and 24 cm were used. Visual cues presented in the cueing conditions were digits 1 cm high and 6 mm wide placed approximately 1 cm left of the to-be-bisected line. The digits ranged from 2 to 8.

Procedures

There were four levels of testing condition: no cue (A); visual cueing, involving reporting the left-end digit (B); circling the left-end digit (C); and circling plus finger tracing (D). In the neutral condition, the subject was asked to mark with a pencil the center of each line presented. In the condition of visual cueing, a digit was placed at the left end of each to-be-bisected line. The subject was instructed to report the digit before bisection. In condition C, the subject was asked to direct his or her right hand leftward to draw a circle around the digit at the left end of the line before bisection. In the condition of circling plus finger tracing, the subject was required to circle the left-end digit, and then trace the to-be-bisected line with the right index finger from its left end toward its midpoint before bisection. Within each condition, there were seven trials for each of the three different line lengths. The 21 trials for each condition were presented in a randomized manner except that no two lines of the same length or exhibiting the same digit for cueing were presented consecutively. Each line was so positioned on the desk that the objective midpoint corresponded to the subject's body midline. Because the effect of right-sided cueing has been well documented, and is not directly relevant to the purpose of this study, no right cueing condition was used.

The deviation of the attempted bisection of each of the lines from the true center was measured as the raw deviation score. To adjust for the differences in line lengths, the bias index (Lin, 1994) was computed as follows:

$$\text{The bias index} = \frac{\text{Raw deviation score}}{\text{Half of the line length}}.$$

A positive sign was given for rightward deviations and a negative sign for leftward deviations. The bias index can range from −1 to 1, with 0 representing no deviation. An average bias index was calculated for each condition across trials for each subject.

A counterbalanced repeated-measures design (Rosenthal & Rosnow, 1991) was employed. Each subject was randomly assigned to one of the following sequences: ABCD, BCDA, CDAB, and DABC, where A, B, C, and D represent the conditions of no cue, visual cueing, digit circling, and digit circling plus finger tracing, respectively. The subjects received the conditions on four consecutive days, one on each day at the same time.

Data Analysis

The specific hypothesis was tested using contrast analysis (i.e., focused analysis of variance) (see Rosenthal & Rosnow, 1985). To reiterate, the hypothesis states that the procedure of circling the digit plus finger tracing would be more effective in reducing neglect than circling alone, and reporting the digit the least effective. Contrast analysis allows data analysis using planned comparisons. For the present study, contrasts numerically reflecting the hypothesis were assigned and the analysis was performed on a 4 × 4 (i.e., one between factor and one repeated factor) mixed analysis of variance (ANOVA). The between factor was condition sequence and the repeated factor was condition order (i.e., the order of administration of the testing conditions). The condition effect was tested in the order-by-sequence interaction using procedures detailed by Rosenthal and Rosnow (1985).

RESULTS

Table 2 shows the bias index associated with each testing condition for each subject. It is clear that the settings of subjective midpoint by each subject was biased, to varying degrees, to the right in conditions A, B, and C. In contrast, a substantial improvement was associated with condition D such that subject performance either fell within the normal limits or even showed a slight leftward bias.

Table 3 displays the mean bias index for each of the 16 cells of the sequence by order display. The sources of variance in the 4 × 4 mixed analysis of variance are shown in Table 4. The focused *F* for our contrast analysis was obtained as follows:

$$F \text{ contrast} = (r^2)(F \text{ conditions} \times df \text{ numerator})$$

where r^2 is the square of the correlation between the contrast weights and the residualized means (see Rosenthal & Rosnow, 1985, for computational details) for the 16 cells.

Table 2. The bias index associated with testing condition

Subject	Experimental sequence	Condition A	B	C	D
1	3	.16	.15	.050	−.029
2	4	.45	.22	.21	.033
3	2	.23	.16	.14	−.084
4	2	.52	.24	.15	.0091
5	1	.12	.097	.078	.032
6	3	.19	.17	.059	.0044
7	1	.11	.082	.069	−.0027
8	4	.17	.090	.042	.029
9	1	.19	.10	.017	−.084
10	2	.15	.18	.16	−.063
11	1	.073	.039	.0082	−.061
12	3	.13	.096	.063	−.0055
13	4	.22	.12	.027	−.028
Mean		.21	.13	.083	−.019
SD		.13	.058	.062	.043

Sequence 1 = ABCD; sequence 2 = BCDA; sequence 3 = CDAB; sequence 4 = DABC. A, B, C, and D represent the conditions of no cue, visual cueing, digit circling, and digit circling plus finger tracing, respectively.

Table 3. The mean bias index and the contrast weight (in parentheses) for each cell of the sequence by order display

	Order 1	2	3	4
Sequence				
1 (ABCD) (n^a = 4)	.18	.11	.12	.0011
	(+3)	(+1)	(−1)	(−3)
2 (BCDA) (n = 3)	.16	.087	−.060	.24
	(+1)	(−1)	(−3)	(+3)
3 (CDAB) (n = 3)	.085	−.011	.21	.14
	(−1)	(−3)	(+3)	(+1)
4 (DABC) (n = 3)	−.0069	.23	.15	.045
	(−3)	(+3)	(+1)	(−1)

Order refers to the order of administration of each testing condition within a sequence. For example, in sequence 1, condition A was presented first and took the first order; condition B was administered in the following day and assumed order 2, etc.

[a]Numbers of subjects in each sequence.

Table 4. Source of variance for the sequence-by-order mixed analysis of variance

Source	*df*	*SS*	*MS*	*F*	*p*
Between subjects	12				
Sequences	3	.077	.026	2.16	.16
Error	9	.11	.012		
Within subjects	39				
Orders	3	.023	.0076	2.53	.078
Orders × Sequences	9	.39	.043	14.33	.0001
Conditions	3	.37	.12	41.00	.0001
Residual	6	.02	.0033		
Error	27	.082	.0030		

Results of the contrast analysis provided substantial support for the *a priori* hypothesis. Circling the digit plus finger tracing was more effective than circling alone, which in turn led to greater improvement than visual cueing, $F(1,27) = 113.36$, effect size $r \approx .96$, $p < .0001$. As expected, differences in the sequence or order of treatment showed no significant effects, although the order effect approached significance. However, the effect of condition was obtained after removing the order and the sequence effects. The condition effect would thus not be confounded by either of these effects.

To estimate the effect of each cueing procedure relative to the neutral condition, further contrast analyses were performed. Results showed that while substantial effects were found with visual cueing ($r = .72$, $p < .001$) and digit circling ($r = .87$, $p < .0001$), the condition of digit circling plus finger tracing effected the largest amount of improvement over baseline ($r = .95$, $p < .0001$).

Several other factors were examined to determine whether and to what extent these factors were related to the relative amount of improvement made under the cueing conditions. Since individual subjects performed at different levels on the baseline (no cue) test, a simple difference score would be inappropriate. Instead, the effectiveness index (Hovland et al., 1949) was employed to avoid misrepresenting the significance of the change scores. For the present study, this measure was computed as follows:

$$\text{Effectiveness index} = \frac{S_1 - S_2}{S_1 - X}$$

where S_1 represents the bias index under the no cue condition, S_2 the bias index under a cueing condition, and X the optimal level of performance assumed to be bias-free (i.e., a bias index of zero). Since 5 of the 13 subjects were close to bias-free when circling plus finger tracing, and the others even showed a leftward bias, the analysis was not performed for this condition since the ceiling effect would obscure any possible relationship under investigation. Correlational analyses showed that age had little effect on the relative amount of improvement made under visual cueing ($r = .092$) and under digit circling ($r = .11$). The effect of time postonset on therapeutic gains under either condition was trivial ($r = .018$ and $r = .026$, respectively). There was, however, a modest relationship between the relative amount of neglect reduction under visual cueing and the severity of neglect on the cancellation tests ($r = .32$ for shape cancellation; $r = .29$ for word cancellation). A higher correlation ($r = .41$) was found between the severity of neglect on each of the cancellation tests and the extent to which the patients benefitted from the digit circling procedure. The observed association between the severity of neglect and the relative amount of neglect reduction under either cueing condition still held good after controlling for the effects of age and time postonset.

To have a better understanding of digit circling as a motor-response-based cueing procedure for left neglect, the effect of this procedure was considered in relation to other reports of the effects of unilateral limb activation under the crossed-hand condition (i.e., hand position on the contralateral side of body). To facilitate comparison and combination across studies, effect size estimates (see Rosenthal & Rosnow, 1991) that are free of sample-size influence were determined for each relevant study (Table 5).

Blind intermittent right hand movement (not visible to the subject) on the left side (Robertson & North, 1992, Experiment 4) produced a modest effect ($r = .30$) on a reading task, relative to the no-movement control condition. Substantially greater effects were obtained on line bisection trials in Halligan et al. (1991, Experiment 2a, 2b) (average $r = .89$), Mattingley et al. (1993, Experiment 1, 2) (average $r = .85$), and the present study ($r = .87$) wherein the right hand was contra-lesionally directed prior to bisection and the hand movements were not concealed. Unseen intermittent left hand movement on the left side during letter cancellation (Robertson & North, 1992, Experiment 2) and reading (Robertson & North, 1992, Experiment 4) resulted in a significant improvement of performance (average $r = .81$). The effect was found to diminish ($r = .32$) when the left-hand movements were on the right side (Robertson & North, 1992, Experiment 2). A starting position to the left of the to-be-bisected line for the left hand (Halligan et al., 1991, Experiment 2a, 2b) greatly reduced left neglect (average $r = .60$). In contrast, use of the left hand tended to be disruptive (average $r = -.56$) when its starting position was on the right.

DISCUSSION

The results lend strong support for the hypothesis that circling the digit plus finger tracing using the ipsilesional hand is more effective in reducing left neglect on line bisection than circling alone. This in turn is better than simple visual cueing. Consistent with previous findings (Butter et al., 1990; Lin, 1993; Nichelli & Rinaldi, 1989; Reuter-Lorenz & Posner, 1990; Riddoch & Humphreys, 1983), unilateral left visual cueing did itself significantly reduce the rightward bias. These findings show that left neglect is ameliorated by enhancing the salience of the left extremity of a horizontal visual display.

Circling the digit resulted in a greater attenuation of left neglect than reporting the digit (cf. Roeltgen et al., 1989). Two mechanisms might mediate the effect of circling. First, circling the digit may cue the perceptual anchoring of the left end of the line ("spatio-motor cueing" hypothesis proposed by Halligan et al., 1991). However, the subjects were not instructed to retain their hand on the left as a starting position for subsequent bisection attempts, nor did they show any tendency to do so. Typically they withdrew the hand toward the ipsilateral hemispace after circling the digit and before bisecting. Alternatively, digit circling may activate the intentional mechanism. Each hemisphere may mediate

Table 5. Studies investigating the effects on left neglect of unilateral limb activation involving the crossed-hand condition

Type of task and studies	Control condition	Experimental condition	Hand[a] visible or not	Effect size r[b]
Line bisection				
Halligan et al. (1991)	Right hand, right side[c]		Yes	
Experiment 2a (n[d] = 1)		Right hand, left side[c]		.88
		Left hand, right side		−.52
		Left hand, left side		.84
Experiment 2b[e] (n = 1)		Right hand, left side		.90
		Left hand, right side		−.59
		Left hand, left side		.17
Mattingley et al. (1993)	Right hand, right side[c]		Yes	
Experiment 1 (n = 6)		Right hand, leftward move for placing a visible left-end mark		.80
Experiment 2 (n = 6)		Right hand, leftward move for placing an invisible left-end mark		.88
The present study (n = 13)	Right hand, right side[c]	Right hand, leftward move for circling a left-end digit before bisection	Yes	.87
Letter cancellation				
Robertson and North (1992)	No hand move		No	
Experiment 2 (n = 1)		Left hand move, right side[f]		.32
		Left hand move, left side		.90
Reading				
Robertson and North (1992)	No hand move		No	
Experiment 4 (n = 1)		Right hand move, left side[f]		.30
		Left hand move, left side		.67

Note: The study of Roeltgen et al. (1989) was not included in this analysis because the authors provided insufficient data to allow the effect size to be calculated.
[a]Refers to the hand used for limb activation in the experimental condition.
[b]Denotes the magnitude of the effect an experimental manipulation produced relative to the control condition. A positive value indicates a beneficial effect on task performance and a negative value, a detrimental effect. The r can range from −1 to 1.
[c]Hand used for line bisection and its starting position.
[d]Number(s) of subjects studied.
[e]A replication study of Experiment 2a conducted 10 days later.
[f]Hand used for intermittent movement during task performance and its position. Right hand was used for letter cancellation.

intentional activation within and toward the contralateral field whether by the ipsi- or contralateral limb (Heilman et al., 1984). If so, moving the right hand toward the contralaterally located target would involve activating the right hemisphere, which would in turn lead to an orienting shift toward the left. Data from the studies summarized in Table 5 are consistent with this proposition. A recent dual task study (Jancke, 1993) provided further evidence that a right arm movement leftward involves activation of the right hemisphere.

By clarifying the diminished effect on neglect reduction of left-hand use in the crossed-hand condition (Halligan et al., 1991; Robertson & North, 1992, Experiment 2), the intentional theory can account for the interaction between the hand deployed and the position of the hand in space. According to this theory, the effect of left-hand use in the contralesional field via a right-hemispheric-activation mechanism would no longer be in force when the left hand was directed toward the ipsilesional side (i.e., the crossed-hand condition) since any rightward movement entails the activation of the left hemisphere, thereby negating the benefit of left-hand use.

A complementary explanation for the limb activation effects comes from the premotor theory of attention of Rizzolatti and Gallese (1988). They proposed that attention and motor preparation are so closely linked that activating one system leads to "recruitment" of the other. Since, according to this theory, spatial attention is a correlate of the organization of a motor act, the selection of a motor plan should automatically produce a shift of attention toward the spatial sector where the action would be executed. A direct implication is that motor output within a hemispatial field by *either* limb would bring about an attentional shift toward that field. The overall results of the present study, together with those investigating the effects of limb activation, suggest that the primary determinant of task performance appeared not to be which hand responds, but the spatial sector toward which the hand was directed. These findings are in accord with both the intentional theory and the promotor theory.

Visuomotor cueing (i.e., digit circling plus finger tracing) produced a larger effect than either visual cueing or digit circling alone. Therefore, the addition of finger tracing engendered an effect above and beyond that of digit circling (see also Hjaltason et al., 1993). With the addition of the component of finger tracing, the visuomotor cueing successfully addressed what was lacking with visual cueing; it provided a bridge between processing the solitary cue and bisecting the line. Tracing also imposed a left-to-right direction of scanning, which maximizes and limits attention to the left segment of the target line. While tracing, patients have to watch what they are doing. (In contrast, Ferro & Kertesz, 1984, required a patient with left neglect to follow the whole of to-be-bisected lines with his index finger before bisection. This did not improve his performance.)

Recent evidence (Binder et al., 1992; Milner et al., 1993) has revealed a tendency of neglect patients to judge the left half of a line as shorter than the right half. Since finger tracing of the left half of the line directs selective attention disproportionately toward that segment of the line, it may enhance that segment's apparent relative size–even to the point of reversing the bias in the bisection performance, as found in most of the subjects in the present study. Note that, in contrast, intentional theory would predict that the left-to-right movement would aggravate neglect. If such an effect occurred, it was overridden.

Given that the circle-trace maneuver completely disposed of the rightward bias in bisection, it follows that the most severe cases of neglect benefitted the most. In other words, the neglect "base-state" had no measurable effect on performance following our maneuver. However skewed attention was to the right, it could be reduced (consistent with the opponent processor model proposed by Kinsbourne, 1970).

The extent to which left neglect is manifested on the word cancellation test or the shape cancellation test varies inversely with the extent to which patients with a right cerebral vascular accident are independent in activities of daily living (Chen Sea et al., 1993; Kinsella et al., 1993). Our finding that the benefit derived from the cueing procedures was positively related to the severity of neglect on either cancellation test implies that those patients whose neglect is particularly disruptive of activities of daily living may benefit the most from the cueing procedures. Do the cueing procedures generalize to subsequent non-cued performance? The practical implications of visuomotor cueing used in the present study were explored in a series of single-subject studies (Lin, 1994). These showed that visuomotor cueing induced significant improvements in both reading and line bisection performance.

ACKNOWLEDGMENTS

This research was supported in part by a grant from the American Occupational Therapy Foundation to the first author. Appreciation is extended to the patients involved as well as staff at the following hospitals in Taiwan for their co-operation and help: Taichung Rehabilitation Hospital, Taichung; Shin Kong Memorial Hospital, Veterans General Hospital, Cathay General Hospital, and Far Eastern Memorial Hospital, Taipei; and Chang Gung Memorial Hospital, Kaohsiung.

REFERENCES

Binder, J., Marshall, R., Lazar, R., Benjamin, J., & Mohr, J.P. (1992). Distinct syndromes of hemineglect. *Archives of Neurology, 49,* 1187–1194.

Bisiach, E., Bulgarelli, C., Sterzi, R., & Vallar, G. (1983). Line bisection and cognitive plasticity of unilateral neglect of space. *Brain and Cognition, 2,* 32–38.

Bisiach, E., Capitani, E., Colombo, A., & Spinnler, H. (1976). Halving a horizontal segment: A study on hemisphere damaged patients with focal lesions. *Archives Suisses de Neurologie Neurochirurgi et de Psychiatrie, 118,* 119–206.

Butter, C.M., Kirsch, N.L., & Reeves, G. (1990). The effect of lateralized dynamic stimuli on unilateral spatial neglect following right hemisphere lesions. *Restorative Neurology and Neuroscience, 2,* 39–46.

Chen Sea, M.J., Henderson, A., & Cermak, S.A. (1993). Patterns of visual spatial inattention and their functional significance in stroke patients. *Archives of Physical Medicine and Rehabilitation, 74,* 355–360.

Ferro, J.M. & Kertesz, A. (1984). Posterior internal capsule infarction associated with neglect. *Archives of Neurology, 41,* 422–424.

Halligan, P.W., Manning, L., & Marshall, J.C. (1991). Hemispheric activation vs spatio-motor cueing in visual neglect: A case study. *Neuropsychologia, 29,* 165–176.

Halligan, P.W. & Marshall, J.C. (1989a). Two techniques for the assessment of line bisection in visuo-spatial neglect: A single case study. *Journal of Neurology, Neurosurgery, and Psychiatry, 52,* 1300–1302.

Halligan, P.W. & Marshall, J.C. (1989b). Perceptual cueing and perceptuo-motor compatibility in visuo-spatial neglect: A single case study. *Cognitive Neuropsychology, 6,* 423–435.

Halligan, P.W. & Marshall, J.C. (1989c). Laterality of motor response in visuo-spatial neglect: A case study. *Neuropsychologia, 27,* 1301–1307.

Heilman, K.M., Bowers, D., & Watson, R.T. (1984). Pseudoneglect in a patient with partial callosal disconnection. *Brain, 107,* 519–532.

Heilman, K.M. & Valenstein, E. (1979). Mechanisms underlying hemispatial neglect. *Annals of Neurology, 5,* 166–170.

Hjaltason, H., Caneman, G., & Tegner, R. (1993). Visual and tactile rod bisection in unilateral neglect. *Cortex, 29,* 583–588.

Hovland, C.I., Lumsdaine, A.A., & Sheffield, F.D. (1949). *Mass communication.* Princeton, NJ: Princeton University Press.

Jancke, L. (1993). A differential effect of concurrent verbal activity on right arm movements rightwards and leftwards. *Cortex, 29,* 161–166.

Joanette, Y. & Brouchon, M. (1984). Visual allesthesia in manual pointing: Some evidence for a sensorimotor cerebral organization. *Brain and Cognition, 3,* 152–165.

Joanette, Y., Brouchon, M., Gauthier, L., & Samson, M. (1986). Pointing with left vs right hand in left visual field neglect. *Neuropsychologia, 24,* 391–396.

Kaplan, E. (1988). A process approach to neuropsychological assessment. In T. Boll & B.K. Bryant (Eds.), *Clinical neuropsychology and brain function: Research, measurement, and practice* (pp. 129–167). Washington, DC: American Psychological Association.

Kinsbourne, M. (1970). A model for the mechanism of unilateral neglect in space. *Transactions of the American Neurological Association, 95,* 143–146.

Kinsbourne, M. (1987). Mechanisms of unilateral neglect. In M. Jeannerod (Ed.), *Neurophysiological and neuropsychological aspects of spatial neglect* (pp. 69–86). Amsterdam: Elsevier Science Publishers.

Kinsbourne, M. (1993). Orientational bias model of unilateral neglect: Evidence from attentional gradients within hemispace. In I.H. Robertson & J.C. Marshall (Eds.), *Unilateral neglect: Clinical and experimental studies* (pp. 63–86). Hove, England: Lawrence Erlbaum.

Kinsella, G., Oliver, J., Ng, K., Packer, S., & Stark, R. (1993). Analysis of the syndrome of unilateral neglect. *Cortex, 29,* 135–140.

Lin, K.-C. (1993, June). Effects of cueing on unilateral neglect: Three single-subject studies. Research poster presented at the 73rd annual conference of the American Occupational Therapy Association, Seattle, WA.

Lin, K.-C. (1994). *The effects of cueing on unilateral neglect in stroke patients.* Unpublished doctoral dissertation, Boston University, Boston.

Mattingley, J.B., Pierson, J.M., Bradshaw, J.L., Phillips, J.G., & Bradshaw, J.A. (1993). To see or not to see: The effects of visible and invisible cues on line bisection judgements in unilateral neglect. *Neuropsychologia, 31,* 1201–1215.

Milner, A.D., Harvey, M., Roberts, R.C., & Forster, S.V. (1993). Line bisection errors in visual neglect: Misguided action or size distortion? *Neuropsychologia, 31,* 39–49.

Nichelli, P. & Rinaldi, M. (1989). Selective spatial attention and length representation in normal subjects and in patients with unilateral spatial neglect. *Brain and Cognition, 9,* 57–70.

Reuter-Lorenz, P.A. & Posner, M.I. (1990). Components of neglect from right-hemisphere damage: An analysis of line bisection. *Neuropsychologia, 28,* 327–333.

Riddoch, M.J. & Humphreys, G.W. (1983). The effect of cueing on unilateral neglect. *Neuropsychologia, 21,* 589–599.

Rizzolatti, G. & Gallese, V. (1988). Mechanisms and theories of spatial neglect. In F. Boller & J. Grafman (Eds.), *Handbook of neuropsychology,* Vol. 1 (pp. 223–246). Amsterdam: Elsevier Science Publishers.

Robertson, I. & North, N. (1992). Spatio-motor cueing in unilateral left neglect: The role of hemispace, hand and motor activation. *Neuropsychologia, 30,* 553–563.

Robertson, I. & North, N. (1993). Active and passive activation of left limbs: Influence on visual and sensory neglect. *Neuropsychologia, 31,* 293–300.

Robertson, I. & North, N. (1994). One hand is better than two: Motor extinction of left hand advantage in unilateral neglect. *Neuropsychologia, 32,* 1–11.

Robertson, I., North, N., & Geggie, C. (1992). Spatio-motor cueing in unilateral left neglect: Three single-case studies of its therapeutic effects. *Journal of Neurology, Neurosurgery, and Psychiatry, 55,* 799–805.

Roeltgen, M.G., Roeltgen, D.P., & Heilman, K.M. (1989). Clinical reports: Unilateral motor impersistence and hemispatial neglect from a right striatal lesion. *Neuropsychiatry, Neuropsychology, and Behavioral Neurology, 2,* 125–135.

Rosenthal, R. & Rosnow, R.L. (1985). *Contrast analysis: Focused comparisons in the analysis of variance.* New York: Cambridge University Press.

Rosenthal, R. & Rosnow, R.L. (1991). *Essentials of behavioral research: Methods and data analysis* (2nd ed.). New York: McGraw-Hill.

Samuelsson, H. (1990). Unilateral spatial neglect after right-brain damage expressed in a line-bisecting task. *Goteborg Psychological Reports, 20,* 31–38.

Schenkenberg, T., Bradford, D.C., & Ajax, E.T. (1980). Line bisection and unilateral visual neglect in patients with neurologic impairment. *Neurology, 30,* 509–517.

Weintraub, S. & Mesulam, M.-M. (1985). Mental state assessment of young and elderly adults in behavioral neurology. In M.-M. Mesulam (Ed.), *Principles of behavioral neurology* (pp. 71–123). Philadelphia: FA Davis.