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Neuropsychologia 39 (2001) 1138–1143

NEUROPSYCHOLOGIA

www.elsevier.com/locate/neuropsychologia

Context and crossover in unilateral neglect

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Received 27 October 2000; received in revised form 7 March 2001; accepted 30 March 2001

Abstract

Patients with left-neglect bisect horizontal lines to the right of true center. Their bisection bias is affected by line length, so that longer lines are bisected further to the right. Patients often crossover and bisect very short lines to the left of true center. We tested the hypothesis that the context in which lines are apprehended accounts for the crossover phenomenon. We replicated previous findings that a line is bisected further leftward when it is preceded by a longer line and further rightward when it is preceded by a shorter line. These contextual effects occur with relatively short and relatively long target lines. Bisection patterns in two different series of lines, one ranging from 10 to 150 mm, and the other from 110 to 250 mm, were investigated. If crossover bisections were simply due to contextual effects then left-sided errors would be observed on bisections of the shorter lines of both series. Our findings did not support this hypothesis. Crossover bisections occurred only with objectively short lines, those shorter than 40 mm. Even though we found significant contextual effects on line bisection biases, these effects per se do not account for the crossover phenomenon. Rather, our data suggest that the absolute length of the line is associated specifically with the crossover phenomenon.

Keywords: Attention; Memory; Line bisection; Spatial neglect

1. Introduction

Patients with left neglect bisect horizontal lines to the right of true center. They make larger absolute errors with longer than with shorter lines [3,6,21]. Interestingly, patients bisect lines of a certain length accurately, and with lines shorter than this length they often crossover and produce leftward errors [5,11,14]. In this paper we investigate how the context in which a particular line is apprehended influences line bisection performances. A theme underlying this investigation is that neglect patients form representations (especially contralesionally) that are unstable and subject to modulation. A better understanding of this modulation will contribute to our knowledge of the dynamics of spatial attention and its contribution to mental representations.

Several hypotheses have been advanced to account for the crossover phenomenon in line bisection. Psychophysical [5,15], mathematical [2], and computational [18] models have been proposed (for a brief review see Ref. [8]). Chatterjee [5], used evidence from neglect dyslexia, to argue that neglect patients confabulate an extension of the line past the left edge of short lines and represent these lines as longer than their objective length. He suggested that a region of disinhibition at the left edge of a rightwardly restricted attentional window might account for such completion (or confabulation). Chatterjee's disinhibition hypothesis [5] has been shown to be plausible in a formal computational model developed by Monaghan and Shillcock [18]. This hypothesis emphasizes the representational instability in neglect that in some instances results in productive, rather than the more often studied omission errors.

Recently, Marshall et al. [16] suggested that crossover effect is part of a general stimulus-context effect. They report that left-neglect patients bisect horizontal lines further leftward when longer lines precede the target lines and further rightward when shorter lines

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0028-3932/01/$ - see front matter
PII: S0028-3932(01)00054-9

precede them. They propose that 'context' effects account for the crossover phenomenon since longer lines in a series usually precede short lines. According to this view, the subjective mid-point of a line is influenced by the line's length relative to other lines, and not by its absolute length. Normal subjects also crossover in their bisections of short lines, albeit to a much lesser extent than neglect patients [6,17]. Mennemeier and colleagues [17] proposed that normal subjects over-estimate small stimuli and underestimate large stimuli, and that this tendency is exaggerated in patients with neglect.

These reports of the contextual effects on how patients bisect lines are reminiscent of a report from almost a century ago [12]. Hollingworth demonstrated that magnitude estimates of lines are affected by the context within which these lines are viewed. At the time psychophysicists found that normal subjects consistently over-estimate magnitudes of smaller stimuli and underestimate larger stimuli for many sensations (including brightness, weight, force, time or spatial extent) [12]. Subjects are very accurate at some point in the range, a point called the 'indifference point'. Hollingworth argued that with line length estimations, this indifference point is not an objective length. Rather, the indifference point varies depending on the ranges of lines presented. The same length of line might be underestimated or over-estimated depending on whether it falls at the larger or the smaller end of a range of lines in which it is presented.

These studies by Marshall et al. [16], Mennemeier et al. [17] and the seminal report by Hollingworth [12] converge to suggest the following account for the crossover in line bisections by patients with neglect. Patient over-estimate small stimuli and underestimate larger ones. Consequently, when presented with a range of lines, they over-estimate the smaller ones and extend it further leftward as suggested earlier by Chatterjee. Importantly, the claim is that the context in which lines appear and not the absolute size of the stimuli is associated with the crossover.

In this study we wished to investigate the adequacy of this contextual explanation for crossover bisections. First, we wished to replicate Marshall and colleagues [16] findings that bisection errors are modulated by the length of lines immediately preceding the target line. We then investigated whether this modulation occurs at different line lengths. Finally we tested the hypothesis that a target line's length relative to other lines, rather than objective length determines the crossover bisections.

2. Method

2.1. Subjects

Eleven left-neglect patients were selected on the basis of their performance on the Behavioral Inattention Test (BIT) battery [23]. Demographic, clinical and BIT data of neglect patients are reported in Table 1. All the patients were right-handed. The Institutional Review Board approved this study.

3. Experiment 1

Five left-neglect patients participated in experiment 1 (patients 1–5 in Table 1). This experiment was designed to investigate whether the length of the previous line affects bisection errors of subsequent lines, as reported previously by Marshall et al. [16]. The presence of a longer line was expected to induce a leftward shift in location of transections on the target line, and vice versa.

3.1. Stimuli

Stimuli were two sets of horizontal lines. In each set 20 context lines were alternated with 20 target lines.

Table 1
Demographic and clinical data of neglect patients[a]

Patient	Sex	Age	Lesion location	VFD	Hemiparesis	BIT
(1) MM	F	65	F P cs	Y	Y	57/146
(2) EB	M	72	bg	N	Y	128/146
(3) LAB	M	61	F T P	Y	Y	27/146
(4) BC	F	58	n/a	n/a	n/a	42/146
(5) JF	M	58	F T P	Y	Y	113/146
(6) OJ	M	58	T P	Y	N	74/146
(7) CG	F	58	T P	Y	N	43/146
(8) LB	F	89	P	N	N	135/146
(9) CC	F	44	P	Y	N	38/146
(10) MT	M	46	T O th	Y	N	14/146
(11) BH	F	62	F T	N	Y	27/146

[a] All patients had strokes. Abbreviations used: Sex: F, female; M, male. Lesion location: F, frontal; P, parietal; T, temporal; bg, basal ganglia; cs, centrum semiovale; th, thalamus; n/a, not available. VFD, visual field defect; Y, yes; N, no.

Table 2
Experiment 1: mean bisection biases (mm), and standard deviations (S.D.) of neglect patients[a]

	Condition 80/40	Condition 20/40	t-test
(1) MM	+2.80 (S.D. = 2.61)	+3.98 (S.D. = 1.79)	t (39) = −2.33; P = 0.025*
(2) EB	+1.75 (S.D. = 1.64)	+2.10 (S.D. = 1.26)	t (39) = −1.35; P = 0.185
(3) LAB	−0.08 (S.D. = 4.02)	+1.20 (S.D. = 3.95)	t (39) = −1.48; P = 0.147
(4) BC	+1.53 (S.D. = 0.48)	+2.80 (S.D. = 0.37)	t (39) = −2.31; P = 0.026*
(5) JF	−1.48 (S.D. = 2.21)	−0.65 (S.D. = 2.84)	t (39) = −1.50; P = 0.142

[a] Single case t-test analyses are also reported. Asterisks indicate significant P-values.

Each line was centered on a 8.5 × 14 inch (21.6 × 35.6 cm) sheet of white paper and oriented along its major axis. In one condition, the context line was 80 mm and the target line was 40 mm (condition 80/40). In the second condition, the context line was 20 mm and the target line was still 40 mm (condition 20/40).

3.2. Procedure

Patients were asked to mark the middle of each line. Stimuli were centered on the patients sagittal midplane and presented on a table at a reading distance. There were no time limits and patients were free to move their head or eyes. The context-line preceded the target-line. Each condition was presented twice in an ABBA order.

3.3. Data analysis

The rightward deviation of the subjective midpoint from the true center of the target lines was measured to the nearest millimeter and was the dependent variable. Bisection errors in 'condition 80/40' were compared to errors in 'condition 20/40', using a paired t-test. Both group analyses and single case analyses were performed.

3.4. Results

Table 2 shows patient performances in each condition. Group analysis showed that bisection bias of condition 80/40 (mean = +0.91, S.D. = 3.18) was significantly further leftward (t-test (199) = −3.81, $P <$ 0.0001) than bisection bias of condition 20/40 (mean = +1.89, S.D. = 3.02). Forty millimeter lines preceded by longer lines were bisected further to the left than the same length lines preceded by shorter lines. This result replicates those of Marshal et al. [16]. Single case analyses showed that this effect was significant in two of five patients.

4. Experiment 2

This experiment was designed to further investigate the above contextual effect. We wanted to determine if the modulation of bisection bias by the presence of longer or shorter lines is present only in lines of relatively small magnitude or also occurs in longer lines. Six additional left-neglect patients (patients from 6 to 11 of Table 1) participated in this experiment.

4.1. Stimuli

Patients performed two tasks. In task 1, stimuli were exactly the same as in experiment 1. In task 2, stimuli were lines of longer lengths. In one condition, the 240-mm context line preceded the 160-mm target line (condition 240/160). In the second condition, the 120-mm context line preceded the 160-mm target line (condition 120/160).

4.2. Procedure and data analysis

Procedure and data analyses were the same as in experiment 1. Patients performed task 1 and then task 2.

4.3. Results

Table 3 shows patient performances on target lines. Mean errors, relative standard deviations, and t-test values are reported for each condition and task. Group analysis showed that bisection bias of condition 80/40 (mean = +0.88, S.D. = 3.52) was significantly further leftward (t-test (239) = −4.86, $P <$ 0.0001) than bisection bias of condition 20/40 (mean = +2.25, S.D. = 3.11). This modulation of errors was also significant individually in two of six patients. In task 2, group analysis revealed that bisection bias of condition 240/160 (mean = +13.36, S.D. = 12.42) was significantly further leftward (t-test (239) = 2.82, P = 0.005) than bisection bias of condition 120/160 (mean = +15.84, S.D. = 12.83). Single case analyses revealed that this bias was significant in two of six patients, although one patient also showed the opposite modulation. In both tasks, transections of target lines preceded by longer lines were placed further to the left (although still to the right of the line mid-point) than on target lines preceded by shorter lines (Fig. 1). The results of experiment 2 replicate those of experiment 1 and suggest that such a contextual effect is evident in target lines of different lengths.

Table 3
Experiment 2: mean bisection biases (mm) and standard deviations (S.D.) of neglect patients in Task 1 and Task 2[a]

	Condition 80/40	Condition 20/40	t-test	Condition 240/160	Condition 120/160	t-test
(6) OJ	+0.98 (S.D. = 0.91)	+3.43 (S.D. = 0.71)	t (39) = −1.97, P = 0.055	+26.88 (S.D. = 2.19)	+35.78 (S.D. = 1.61)	t (39) = −3.432, P = 0.0014*
(7) CG	+4.15 (S.D. = 2.37)	+4.05 (S.D. = 2.55)	t (39) = 0.197, P = 0.845	+7.88 (S.D. = 14.53)	+20.10 (S.D. = 8.54)	t (39) = −4.73, P = 0.00003*
(8) LB	+1.03 (S.D. = 1.37)	+1.50 (S.D. = 1.09)	t (39) = −1.68, P = 0.099	+16.55 (S.D. = 4.83)	+13.13 (S.D. = 6.26)	t (39) = 2.81, P = 0.008*
(9) CC	−0.70 (S.D. = 3.13)	−1.03 (S.D. = 2.55)	t (39) = 0.52, P = 0.606	+5.35 (S.D. = 6.17)	+5.45 (S.D. = 7.14)	t (39) = −0.06, P = 0.950
(10) MT	−0.23 (S.D. = 2.08)	+3.30 (S.D. = 1.49)	t (39) = −8.09, P<0.0001*	+15.35 (S.D. = 12.07)	+13.68 (S.D. = 9.48)	t (39) = 0.749, P = 0.458
(11) BH	+0.05 (S.D. = 2.40)	+2.28 (S.D. = 2.30)	t (39) = −5.44 P<0.0001*	+8.15 (S.D. = 2.96)	+6.93 (S.D. = 4.51)	t (39) = 1.41, P = 0.168

[a] Single case t-test analyses are also reported; asterisks indicate significant P-values.

5. Experiment 3

Given the results of experiments 1 and 2 (i.e. leftward shift of bisection bias in the context of longer lines) we wished to test whether the commonly observed crossover effect occurs because shorter lines (under 40 mm) are generally presented in a series with longer lines. To do so, we examined bisection errors of lines belonging to two different ranges. If the crossover is entirely due to contextual effects, then it should be observed in bisections of the shortest lines in each set, even though the ranges of absolute lengths varied across both sets. All 11 patients participated in this experiment.

5.1. Stimuli

The stimuli comprised two sets of 15 horizontal lines of different lengths. Each line was centered on a 8.5 × 14 inch (21.6 × 35.6 cm) sheet of white paper and oriented along its major axis. In one condition, lines varied from 10 to 150 mm (in increments of 10 mm). In the second condition, lines ranged from 110 to 250 mm (also in increments of 10 mm).

5.2. Procedure

Each line was presented randomly within the set. Stimuli were presented in an ABBA order.

5.3. Results

Percent errors for bisections on the shortest lines of both sets (10, 20, 30, and 40 mm, and 110, 120, 130, and 140 mm) are reported in Fig. 2. Crossover bisections were only present for shortest lines of the range with shorter lines and not on the shortest lines of the range with longer lines.

6. Discussion

The goal of our study was to examine the way in which context influences how patients with neglect bisect lines. The results of the first experiment confirmed that left-neglect patients bisect lines further leftward when preceded by a longer line, and further rightward when preceded by a shorter line, replicating Marshall et al.'s findings [16]. The second experiment established that this modulation also occurs with longer target lines. We saw similar modulation of bisection errors when the target lines were 40 mm and when they were 160 mm long. From these results one might expect that the crossover might be found at any length of line (note that crossover is sometimes to be seen with quite long

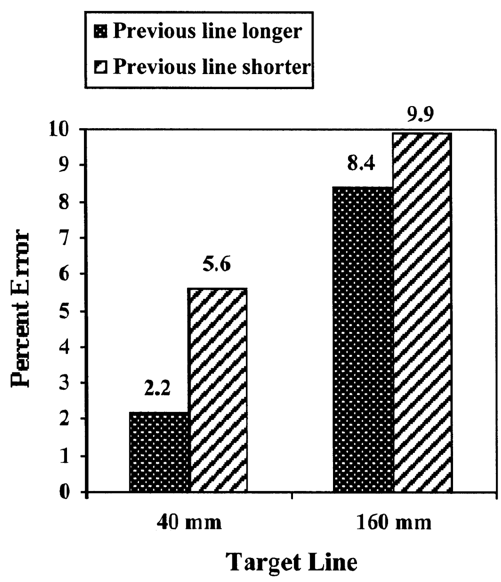

Fig. 1. Experiment 2: Percent errors on bisection by neglect patients. In Task 1, a target line 40 mm long was preceded by longer (80 mm) or shorter (20 mm) context lines. In Task 2, a target line 160 mm long was preceded by longer (240 mm) or shorter (120 mm) context lines.

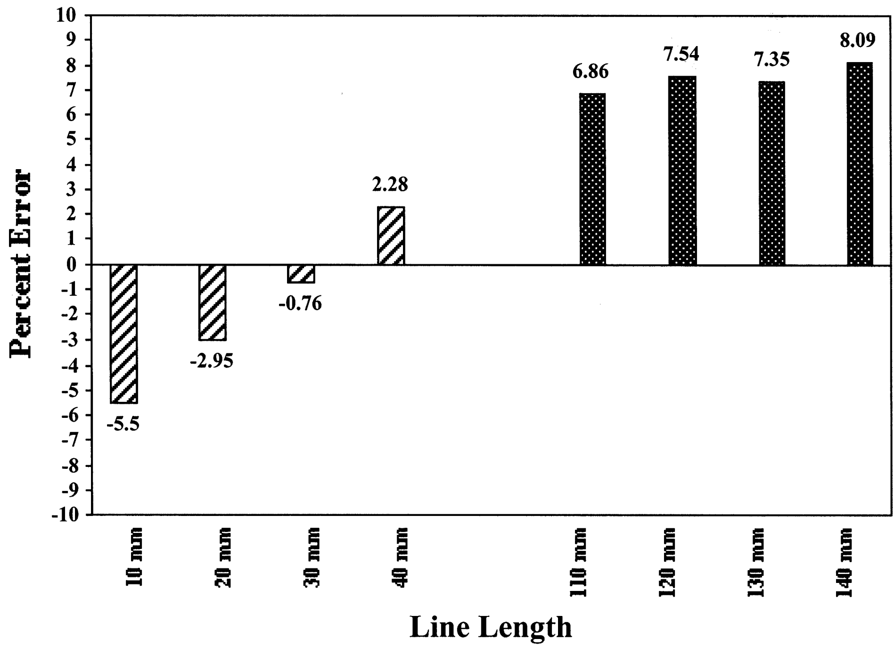

Fig. 2. Experiment 3: Percent errors by neglect patients for the shortest lines of each series 10, 20, 30, 40 mm and 110, 120, 130 and 140 mm. Crossover is present only in the shortest lines.

lines [1,10]). What might be relevant is whether a particular line is at the shorter end of a range of lines presented. In the third experiment, patients bisected sets of lines of two different ranges. In one range, the shorter lines were 10, 20, 30 and 40 mm. In the other range they were 110, 120, 130 and 140 mm long. If crossover bisections occur because shorter lines are over-estimated when apprehended in the context of longer lines, crossover bisections should be found on the shortest lines in both ranges. As shown in Fig. 2, crossover bisections were only seen on 10-, 20- and 30-mm lines and not at 110, 120, or 130 mm.

Our data indicate that contextual effects per se (i.e. the presence of longer preceding lines) do not account for crossover phenomena. As we mention in the introduction, contextual effects also occur in normal subjects [12]. Contextual effects probably occur with judgments of different kinds of stimuli, including non-spatial ones [8]. We suspect that these effects are exaggerated in patients with neglect, although this hypothesis has not been tested directly in normal subjects using line bisection tasks. With respect to the crossover phenomenon in patients with neglect, the absolute rather than relative lengths of lines appear to be crucial. We found crossover bisections only on short lines, those under 40 mm, and not on longer lines that were the shortest in a given range. Similarly, in a single case study, Marshall and Halligan [15] reported that crossover bisections occurred on very short lines even when they were the sole members of the set ([15], exp. 6). Both these results argue that crossover bisections occur specifically with short stimuli. Ishiai and colleagues [13] also point out that neglect patients view short lines (less than 100 mm) differently than longer lines. They find that neglect patients' bisections are influenced by the absolute lengths of short lines and by the visual angle subtended by longer lines presented at different distances.

Several factors can modulate neglect patients' direction and magnitude of errors on line bisection tasks. The length of lines clearly affects the size of errors. Longer lines are consistently associated with greater errors. As we have described previously the pattern of bisections as influenced by the length of lines can be described mathematically by power functions [6,7]. Patients' line bisections may also be influenced by visual illusions [22]. We have shown that patients make greater errors with lines that appear longer, even when these lines encompass identical horizontal extents [20]. Line bisections are also modulated by the spatial location of lines [9] and by whether the eyes or limbs guide the point of transection [4,19]. All these influences on line bisection performances are spatial or spatio-motor factors. To this list we add the influence of contextual or temporal factors. Data from our first two experiments, consistent with those reported previously by Marshall et al. [16], demonstrate that performance on the current stimulus is affected by the magnitude of the previous stimulus. Such temporal influences on judgments of stimuli 'on-line' also occur with stimuli that are not intrinsically spatial, such as weight perception [8].

Contextual or temporal effects on 'on-line' perceptions in neglect have not been well studied. We have argued elsewhere that characteristics of previous stimuli may be assimilated into on-line perceptions, especially when attention is impaired [8]. However the properties of such influence, and the level of representation at which this influence occurs need further study. Contextual and crossover effects in line bisection by neglect patients draw attention to two aspects of the neglect syndrome. First, patients seem disproportionately influenced by previous stimuli [8]. At this point, we simply do not know very much about the properties of these temporal effects. Second, any adequate theory of neglect and spatial attention or representation must also accommodate productive manifestations in contralesional space [5,18].

Acknowledgements

This study was supported by a grant from the NIH: NS37539. We also appreciate Jesse Calhoun's help with data collection.

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