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Motor and perceptual factors in pseudoneglect

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Abstract

An important variant of the traditional line bisection task has involved a mechanical device invented by Bisiach and his colleagues (Bisiach et al. Perceptual and premotor factors of unilateral neglect. Neurology 1990;40:1278–81 [3]). This tool was devised to dissociate motor from perceptual factors in hemi-spatial neglect, by means of a mid-line indicator which moved ‘congruently’ or ‘non-congruently’ with the direction of hand movement. In the non-congruent condition, Bisiach was able to demonstrate a reduction, or reversal, of the direction of bisection error in a number of patients with neglect. These errors were interpreted as instances of ‘motor’ neglect. Bisiach et al. [3] also tested 10 normal subjects, who did not differ on the two conditions of the task. However, the original experiment [3] required the use of the right hand only, and it has since become clear that bisection errors in normal subjects (i.e. pseudoneglect) are more substantial when dextral subjects use their left hands. By using a modified version of the Bisiach Tool we show that there is an effect of the motor versus perceptual condition on this task, but only when subjects use their non-dominant (left) hand. © 1999 Elsevier Science Ltd. All rights reserved.

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1. Introduction

The traditional line bisection task [36] provides a highly sensitive measure of lateral spatial abilities in unilateral visual neglect [19, 24, 34]. Patients with this disorder tend to bisect horizontal lines well to the right of centre [33]. Two main theoretical approaches have been proposed to account for why these patients make such large errors in line bisection [see also 1, 4, 28]. The perceptual-attentional hypothesis [12, 16, 24] argues that errors occur because of inattention to the left hemispace, as a result of damage to the dominant (right hemisphere) attentional system. A second, motor, account stresses the failure of such patients to fully execute movements in, or towards, the contralateral hemispace (‘directional hypokinesia/hypometria’), due to under-activation of right-hemisphere premotor systems [13, 18].

Several experiments have attempted to clarify this motor versus perceptual distinction in neglect—each involving different experimental materials, and different patient groups. The results of these experimental manipulations have not always been consistent. However, they do suggest that ‘perceptual’ factors appear to be the predominant cause of neglect in the majority of patients, with ‘motor’ factors predominating in the remainder [see 20, 25]. One example is the ‘Landmark’ Task [17, 27] in which patients were asked to judge mid-transected lines by pointing to the end ‘closer’ to the prebisected centre. Predominantly motor factors appeared to underlie the performance of one of the patients tested. This is consistent with the finding that leftward cueing reduces the amount of rightward error seen in neglect patient’s performance on the traditional line bisection task [14, 29, 30]. A similar attempt at dissociating perceptual and motor factors in neglect has been made by using a cancellation task [35] in which the left-right features of the line were reversed using mirrors, with and without cueing [5]. In this task, a minority of neglect patients [35] were found to show a directional hypokinesia powerful enough to overcome perceptual factors.

1.1. The bisection tool

The fact that either the perceptual or motor deficit might form the basis of neglect in any individual patient was first demonstrated in a celebrated experiment conducted by Bisiach et al. [3]. They invented a mechanical device in which the patient moved a lever, which controlled a vertical steel bar into the mid-point of the line.

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The device could operate in two different ways. In the ‘congruent’ condition, the vertical bar moved in the same direction as the patient’s hand movement—producing the standard rightwards error in all patients with left neglect. However, in the ‘non-congruent’ condition, the vertical bar moved in the opposite direction to hand movement. They argued that, in this condition, the perceptual and action-related determinants were decoupled. It was expected that patients with leftward hypokinesia would resist moving the lever leftwards—thus they would be unable to move in the direction that would produce the expected (rightward) error seen in patients with left neglect. Hence, in patients with ‘motor’ neglect, the magnitude of the rightward bisection error would be reduced in the non-congruent condition. Bisiach et al. [3] tested 15 patients showing left neglect, and two patients showed this transection pattern to a marked degree: moving the level rightwards in the non-congruent condition, thus setting the vertical bar to the left of the objective midpoint. This resulted in the paradoxical effect of patients with left neglect appearing to bisect the line to the left of centre.

1.2. Pseudoneglect

If left neglect is the result of the loss of a dominant right hemisphere attentional system, we might anticipate that, in the neurologically normal, this system might dominate—resulting in the opposite pattern of lateral attention to that seen in the neurological population. In this context, it is interesting to note that when normal subjects are asked to bisect a horizontal line centrally, they typically transect the line to the left of centre. However, the magnitude of the error is far smaller than that seen in the neurological population [9, 26, 31, 32]. This phenomenon has been labelled ‘pseudoneglect’ [6], and prototypically involves leftward errors in normal adult dextrals, contrasting with the rightward errors found most commonly in neurological patients. However, the trend to bisect lines significantly to the left of centre in normal adult dextrals has not been found in all studies [15, 22]. Some studies have reported non-significant rightwards errors [29, 33], and others found that roughly half of subjects bisected slightly to the left and the other half slightly to the right [21]. The reasons for such variation in performance appears to be partly explicable by differences in the standard administration procedures, and by the different strategies employed by subjects while performing the task, for example by the variation in the scan strategy used [10].

Pseudoneglect can also be modulated by other parameters, such as gravitational and corporeal co-ordinates [7], handedness, line length [31, 32], long-term blindness [8], and reading habits [11]. A significant development has been an understanding of the importance of the hand used when performing the task. In a recent study, Brodie and Pettigrew [10] found that the magnitude of the leftward bisection error is far larger, in dextrals, when the left hand is used [10].

In this context, it would be appropriate to consider whether pseudoneglect has ‘motor’ and ‘perceptual’ determinants in normal subjects, as Bisiach and others demonstrated in the case of neurological patients. The original Bisiach et al. [3] study did test ten normal subjects, in both the congruent and non-congruent conditions, but failed to find any significant effects resulting from non-congruent motor action. Importantly, the failure to find any significant effects in the non-congruent condition, in the normal population, may have been due to the fact that subjects were tested exclusively with their right hand. As noted above, recent research [10] has suggested that bisections with the left hand tend to elicit far greater leftward errors. Thus, it might be appropriate to investigate the effect of non-congruent action using the Bisection Tool in normal subjects, using both hands.

2. Experiment 1

2.1. Method

2.1.1. Subjects

Twenty subjects aged between 20 and 25 participated in the experiment. The same subjects also took part in Experiment 2. Ten subjects were female and ten were male. All subjects were strongly right-handed, which was assessed by administration of the 12-item Annett Handedness Inventory [2].

2.1.2. Materials

One hundred black lines (15 cm long and approximately 1 mm wide) were placed horizontally and centrally on ten sheets of A4 paper with ten lines on each sheet. By means of a rectangular movable window, only a single line was visible to the subject at any given time, thus preventing direct comparisons to previously completed bisections.

2.1.3. Procedure

Subjects were seated at a table opposite to the experimenter, and were positioned so that the objective midpoint of the lines lay in mid-axis to their trunk. They were instructed to bisect each line by marking with a fine pen what they assumed to be the mid-point of each line. Fifty lines were bisected using the right hand, and fifty lines using the left hand. The experimenter determined the magnitude of error (in mm), assigning positive values to errors deviating to the right of subject’s mid-line, and negative values to errors to the left of the mid-line.

2.2. Results

The mean error scores showed a leftward deviation with both the right hand (mean = -0.77, S.D. = 2.09) and the left hand (mean = -1.69, S.D. = 2.00). A t-test revealed that mean deviations made using the right hand were not significantly different from zero ($t = -1.65$, df = 19, $P > 0.05$), although mean deviations made using the left hand were significantly different from zero ($t = -3.78$, df = 19, $P < 0.01$). Comparisons made between left handed deviations and mean right handed deviations failed to reach statistical significance ($t = -1.88$, df = 19, $P = 0.08$).

Analysis of absolute errors revealed that errors made with the right hand (mean = 1.87, S.D. = 1.13) were significantly different from zero ($t = 7.43$, df = 19, $P < 0.001$). Errors with the left hand (mean = 2.18, S.D. = 1.42) were also significantly different from zero ($t = 6.86$, df = 19, $P < 0.001$). There was no significant difference between left and right handed bisection errors ($t = 1.09$, df = 19, $P > 0.05$).

3. Experiment 2

3.1. Method

3.1.1. Materials

A special device, the Bisection Tool [3], was constructed for the purpose of the experiment (see Fig. 1a,b). The tool was a modified version of the tool originally used by Bisiach et al. [3]. Subjects could reach underneath the apparatus with either hand, although their hand was obscured from subjective viewing by a panel in front of the tool. Subjects could freely move either one of two levers, allowing them to control the horizontal movements of a vertical steel bar, which could be viewed within a small screen (20 cm × 2 cm), placed approximately 30 cm directly in front of them. One lever moved the vertical bar in a manner that was congruent to the direction in which the subjects moved their hand. In the non-congruent condition, a second lever ran counter to the subject's hand movement, by means of a pulley device. Thus, subjects could move the lever in a rightward direction, but would see the upright bar move leftwards across the screen. When changing from the non-congruent to the congruent condition, or vice versa, one lever could be moved out of reach (and its associated bar moved out of sight) at the edge of the screen. The experimenter gained privileged access to a metal ruler (0–200 mm) behind the tool, which indicated the magnitude of the subject's error to the nearest millimetre.

3.1.2. Procedure

The experimenter familiarised subjects with the Bisection Tool by demonstrating the congruent and non-congruent conditions. Subjects were asked to move the upright bar into the centre of the screen until it reached a point that they considered to be the true mid-line. In an attempt to control for any possible effects of starting side (see [10]), subjects were instructed to move the bar to alternate starting sides at the beginning of each bisection attempt. Subjects completed 96 bisections, in 4 blocks of 24 trials. The four following conditions were systematically varied in a 'Latin Square' sequence: (1) right hand congruent, (2) left hand congruent, (3) right hand non-congruent, (4) left hand non-congruent.

3.2. Results

Analysis of the mean error scores indicated a predominant leftwards error on all conditions (Table 1). T-tests revealed that these deviations were significantly different from zero in both the congruent condition (right hand ($t = -4.63$, df = 19, $P < 0.001$), left hand ($t = -6.09$, df = 19, $P < 0.001$)), and the non-congruent condition (right hand ($t = -5.33$, df = 19, $P < 0.001$), left hand ($t = -5.01$, df = 19, $P < 0.001$)). In the congruent condition, left handed deviations were significantly different from right handed deviations ($t = -2.65$, df = 19, $P < 0.05$). No significant difference was found between left and right handed deviations in the non-congruent condition.

There was a significant correlation between performance on the traditional line bisection task and the congruent condition of the Bisection Tool for the left hand ($r = +0.56$, $P < 0.05$), but not for the right hand ($r = +0.20$, $P > 0.05$).

Errors were submitted to an analysis of variance (ANOVA) with factors of Hand (left, right) and Task (congruent, non-congruent). There was no significant main effect for Hand ($F = (1,19) = 0.96$, $P > 0.05$), or Task ($F\ (1,19) = 0.43$, $P > 0.05$). However, there was a significant interaction between Hand and Task ($F\ (1,19) = 5.54$, $P < 0.05$). A simple main effects analysis revealed that left handed deviations in the non-congruent condition were significantly less than in the congruent condition ($F\ (1,38) = 4.75$, $P < 0.05$). In the congruent condition, the analysis also revealed that left handed deviations were significantly greater than right handed deviations ($F\ (1,38) = 5.86$, $P < 0.05$). No other differences were found to be significant.

The data were also re-cast so that individual subjects were classified according to the relative direction towards which they shifted, when introduced to non-congruent action (see columns C and F, Table 1). When using their right hand, 5/20 subjects shifted right, 14/20 subjects shifted to the left, and one subject did not shift mean transection position. In contrast, when using their left hand, 13/20 shifted to the right, but only 7/20 shifted to the left, thus showing a significantly different shifting pattern for left and right hands ($\chi^2 = 5.87$, df = 1, $P < 0.05$).

Analysis of absolute errors in Experiment 2 showed that right handed congruent errors (mean = 1.28, S.D. = 1.00) were significantly different from zero

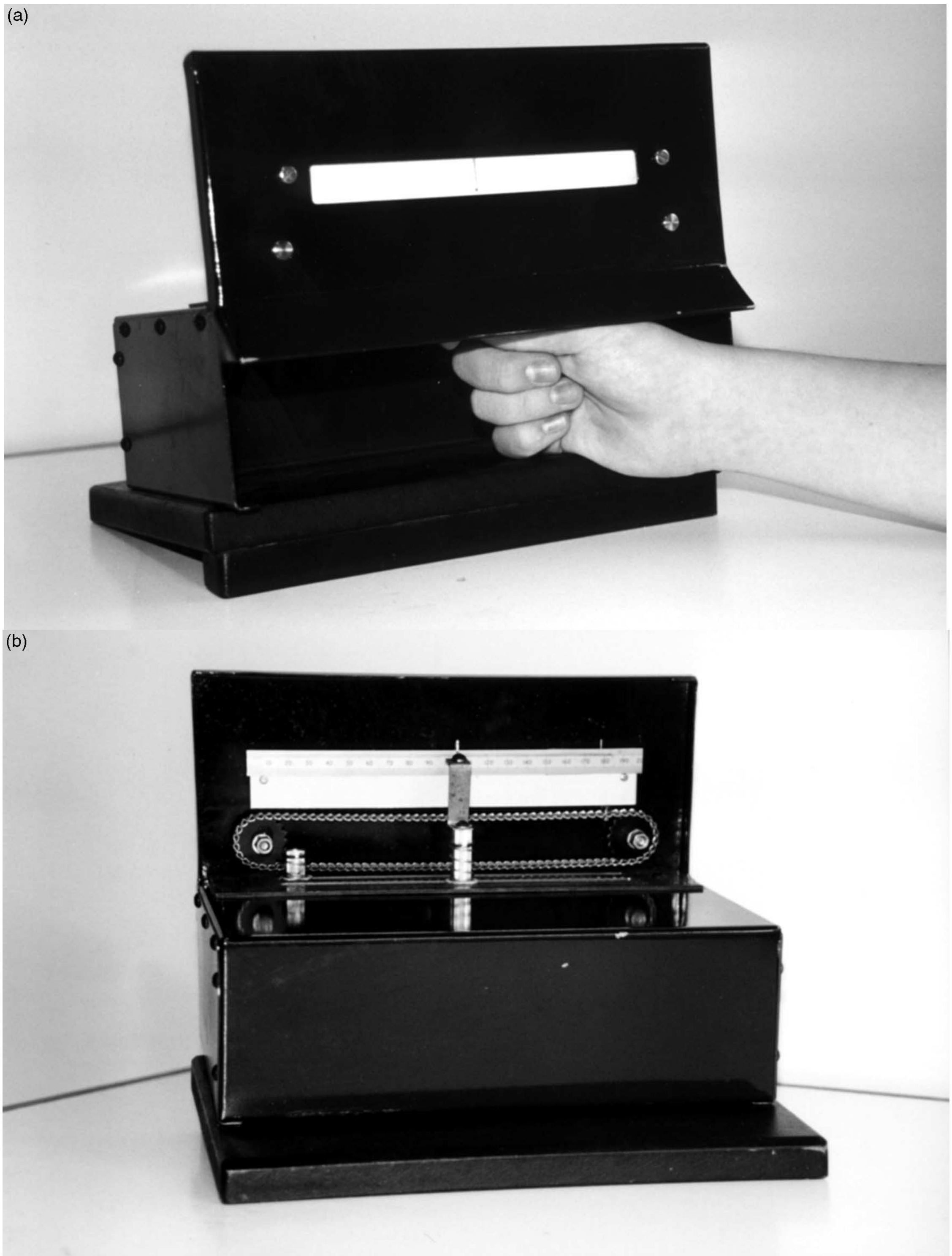

Fig. 1. (a) Subject's view of the Bisiach Tool in the non-congruent condition. The panel which normally obscures the subject's view of their hand has been removed to reveal that the rightwards movement of the hand causes the vertical steel bar to travel leftwards. (b) Examiner's view of the Bisiach Tool showing the pulley device by which non-congruent action is produced. The ruler indicates the magnitude of the subjects' deviations.

($t = 5.72$, df = 19, $P < 0.001$). Errors with the left hand (mean = 1.76, S.D. = 1.28) were also significantly different from zero ($t = 6.14$, df = 19, $P < 0.001$). There was no significant difference between left and right handed bisection errors ($t = 2.08$, df = 19, $P > 0.05$). Comparisons between the traditional line bisection task and the Bisection Tool revealed that the two tasks did not correlate with either the right hand ($r = +0.28$,

Table 1
Mean displacement errors (in mm) for visual line bisection as a function of hand used and congruency of hand movement

	Hand					
	Left			Right		
Subject	A Congruent	B Non-congruent	C Direction of shift	D Congruent	E Non-congruent	F Direction shift
1	−2.25	−0.96	Right	−1.13	−2.50	Left
2	−0.88	−0.67	Right	−0.88	−1.88	Left
3	−0.42	−2.08	Left	−0.08	−0.79	Left
4	−0.83	+0.96	Right	−1.00	−1.08	Left
5	−2.17	−1.79	Right	−0.54	−1.54	Left
6	−2.21	−2.42	Left	−1.33	−1.63	Left
7	−1.63	−0.96	Right	−1.29	−0.88	Right
8	−2.58	−2.00	Right	−0.33	−2.71	Left
9	−4.92	−3.08	Right	−4.17	−4.17	=
10	−2.42	−2.33	Right	−1.88	−2.46	Left
11	−1.33	−2.58	Left	−2.83	−2.75	Right
12	−0.13	−0.46	Left	−0.17	−0.33	Left
13	−1.75	−1.04	Right	−1.08	−1.92	Left
14	+0.04	+0.67	Right	+1.04	+0.58	Left
15	−1.79	−0.71	Right	+0.04	+0.13	Right
16	−0.13	−0.54	Left	−1.63	+0.21	Right
17	−0.71	−1.29	Left	−0.88	−1.25	Left
18	−2.25	−1.38	Right	−1.58	0.00	Right
19	−2.75	−1.96	Right	−1.21	−1.75	Left
20	−4.08	+0.24	Right	−2.52	−3.16	Left
Mean	−1.76	−1.22		−1.17	−1.49	
S.D.	1.29	1.09		1.13	1.25	

$P > 0.05$) or the left hand ($r = +0.35$, $P > 0.05$). When the absolute errors were submitted to the simple main effects analysis by Hand and Task, no main effects or interactions reached significance.

4. Discussion

The findings of the present study replicate the presence of a small leftward bias in line bisection [9, 27, 32]. This bias occurred regardless of hand used, although in the first experiment (involving the traditional line bisection task), this bias only reached significance when the left hand was used. It therefore appears that the tendency to bisect lines to the left of centre is a fairly robust phenomenon, when the left hand is used. The tendency of the left hand to elicit greater leftward deviations than the right hand [10] was not replicated in the first experiment, but was shown using the congruent condition of the Bisection Tool. It is noteworthy that the magnitude of the subjects' errors on the traditional line bisection task were consistent with the left scanning direction results [10] previously observed (2.00 mm deviation for the left hand and −0.85 mm for the right hand).

The analysis of bisection errors across both the traditional task and the congruent condition of the Bisection Tool revealed that errors were significantly correlated for the left hand, but not the right hand. The analysis of absolute errors suggested that the two tasks were not comparable. This result may have been due to the fact that there was no control over start side in Experiment 1, whereas start side was controlled for, and the results pooled, in Experiment 2.

The results of the second study appear to both replicate and extend the account of Bisiach et al. [3], who found that, with normal subjects, non-congruent motor action with the right hand did not reduce or reverse the magnitude of pseudoneglect. However, with left hand performances (the hand that elicits the leftward bias most clearly [10, 26, 32]), the magnitude of the leftward bias was reduced in the non-congruent condition. This was demonstrated by the significant ANOVA interaction between the hand used and the task employed, and also shown when the data were analysed at an individual subject level. Using the left hand, 65% of subjects showed a significant rightwards shift, relative to the congruent condition. However, with the right hand, only 30% of subjects shifted rightwards. Thus, the Bisection Tool produced an effect in normal subjects of reducing the magnitude of pseudoneglect, but only when the left hand was used. This effect might be argued to be analogous to 'motor' neglect in the neurological population [3], and would have gone unrecognised in the original Bisiach study because the investigators did not test bisection performance using the left hand.

We should also consider other possible explanations for the phenomenon. For example, this effect may have resulted from the selective activation of the right hemisphere by the use of the left hand, causing preferential leftward movement and thus a lessening of the leftward bias in the non-congruent condition. Brodie and Pettigrew [10] emphasise that activation of the right hemisphere by the left hand is the most plausible explanation for why both leftward and rightward scanning elicits significant leftward deviations of the left hand, suggesting that the degree of leftward deviation in normal subjects results from an interaction between right hemispheric activation and unilateral allocation of attention. This is also consistent with reports of patients with neglect. For example Marshall and Halligan [22] reported the case of a severe visuo-spatial neglect patient who revealed reliable left neglect on a cancellation task, but improved when the left hand was used. The patient also showed normal performances on the line bisection task with the right hand but right neglect when using the left-hand.

With these data in mind, it might be appropriate to further investigate the performance of normal subjects involving the magnitude of transection as a function of line length using the Bisection Tool, and to investigate the performance of right handed subjects in comparison to left handed subjects. Future experiments might also examine the influence of start side on both congruent and non-congruent conditions.

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