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Horizontal visual motion modulates focal attention in left unilateral spatial neglect

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Abstract

Patients with unilateral spatial neglect are impaired in directing focal attention toward the contralesional side of space. Provision of static spatial cues on the neglected side has previously been shown to help overcome this deficit. Common movement of visual stimuli may also guide the allocation of spatial attention, although such effects have not been examined in patients with unilateral spatial neglect. Eleven patients with right hemisphere damage and clinical evidence of left unilateral spatial neglect, and 11 matched, healthy controls were tested on a task of horizontal line bisection. Lines were presented on a computer display, with a neutral, static, or slowly drifting, random dot background. Under conditions of motion, background stimuli drifted either leftward or rightward, across the full width of the display, at speeds that did not elicit optokinetic nystagmus or perceptual aftereffects. Controls were accurate in all conditions, and showed minimal effects of background conditions. By contrast, patients with left unilateral spatial neglect were sensitive to leftward background motion, showing a significant leftward shift in bisection error, relative to neutral, static, and rightward moving backgrounds. There was no significant effect of rightward motion in comparison with the neutral and static conditions. The extent to which patients were susceptible to the effects of background motion was not related to severity of unilateral spatial neglect, as measured by clinical tests. The benefits of leftward motion may reflect activity of preserved motion processing mechanisms, which provide input to an otherwise dysfunctional attentional network. The use of visual motion to assist in contralesionally guiding focal attention may be useful in the rehabilitation of unilateral spatial neglect.

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Unilateral spatial neglect provides a unique opportunity for studying the mechanisms by which the normal brain mediates the allocation of attention in space. After unilateral hemisphere damage, patients with unilateral spatial neglect may exhibit a mix of apparently impaired and preserved attentional capacities, depending on the precise locus of cerebral damage[1-3] and specific task demands.[4-6] One of the most fruitful approaches to the study of both normal and impaired attentional processes has involved the use of discrete visuospatial cues to systematically manipulate the locus of attentional allocation. Such cues have been used in the task of horizontal line bisection,[7,8] where attended and unattended regions are mapped in the spatial domain.

In the absence of visual cues, many patients with left unilateral spatial neglect after right hemisphere damage have been shown to bisect horizontal lines to the right of the true midpoint.[9] The extent of this rightward error is a constant proportion of line length,[10,11] suggesting that patients may have some residual (albeit suboptimal) capacity to perceive apparently "neglected" portions of the stimulus line. Indeed, the existence of implicit processing of "neglected" stimuli is now well documented.[12-14]

By contrast, the rightward errors exhibited by these patients may be substantially reduced, and occasionally reversed to become leftward errors, by requiring patients to direct focal attention to the left endpoint of the line before bisection.[7,8,15,16] On the other hand right sided cueing has been shown in some studies to significantly increase the magnitude of rightward bisection errors,[8,16] but in others to have no significant effect when compared with performance in the absence of cues.[7,15]

One possible explanation for these cueing effects in patients with unilateral spatial neglect is that focal attention, which has been considered to operate as a spotlight or zoom lens,[17,18] is not spontaneously directed to the left endpoint of the line.[19] When instead focal attention is drawn to the left by a lateralised cue, performance may approach normality. As well as this lateralised impairment in directing focal attention contralesionally, it has been proposed[11] that such patients have an underlying perceptual deficit in matching horizontal extents. This additional impairment may account for the high variability of patients' bisection judgements, and explain the occasional findings of significant leftward errors with left sided cues[7] and with short (< 5 cm) line lengths.[11]

Recent studies of normal attentional processes, however, suggest that the spotlight and zoom lens metaphors may not always be adequate, as attention may sometimes be allocated to non-contiguous regions of visual space. In particular, the Gestalt grouping principles such as good continuation and common movement[20] may reflect the operation of an attentional system that operates on perceptual groups which are sometimes spatially dispersed, rather than being allocated to circumscribed and contiguous regions of the visual field. For example, it has been found that spatially distant distracters, which move with a visual target, produce more interference with a central target (that is, have a greater effect on attentional processing) than do static distracters, despite the fact that the moving distracters are located more peripherally than the static ones.[21] There is also evidence from a visual search paradigm that attention may be selectively allocated to spatially dispersed, moving stimuli, which are intermingled with static stimuli.[22] Thus common movement is one perceptual grouping principle that may guide the allocation of visuospatial attention.[23]

Although the effects of visual movement on attentional processing in normal subjects is now well documented, little is known about its effects in patients with unilateral spatial neglect. It is known that patients with unilateral spatial neglect have normal contrast sensitivity thresholds for both static and horizontally moving sinusoidal gratings.[24] Moreover, patients with left unilateral spatial neglect are essentially unimpaired in detecting the direction of movement, either toward or away from the "neglected" side.[24] In view of the absence of higher level disturbances of movement vision, patients with unilateral spatial neglect should be susceptible to attentional modulation by moving visual stimuli.

One previous study examined the effects of apparent motion of discrete visual cues positioned around the left endpoint of horizontal lines.[25] The magnitude of rightward bisection errors made by patients with left unilateral spatial neglect was significantly reduced under such conditions, compared with those in which cues were static, or in which they seemed to move in the region of the subjective midpoint. Interestingly, the benefits of lateralised dynamic stimuli occurred despite the patients' apparent lack of awareness of their presence, suggesting that the effects were in some sense automatic or implicit. Moreover, the reduction in rightward bisection errors occurred even among patients with documented left visual field defects.

In another study,[26] patients with a damaged right hemisphere and normal controls were exposed to a rapidly moving strip of luminous dots, which, after extended exposure, induced a horizontal, optokinetic nystagmus. Patients with a damaged right hemisphere, with and without unilateral spatial neglect, and healthy controls all showed significant displacements on a horizontal line bisection task, which were congruent with the direction of movement. The mechanism for these effects is not entirely clear, although it seems likely that optokinetic stimulation, along with caloric[27] and neck muscle[28] stimulation, may modulate the activity of vestibular systems responsible for calibrating spatial coordinate frames.[29]

The aim of the present study was to examine the effects of full field visual motion, as opposed to apparent motion of discrete, lateralised cues. In addition, by presenting subjects with a slowly drifting, low contrast visual background, it was possible to document phasic changes in the allocation of spatial attention, without inducing optokinetic nystagmus or the visual after effects typically associated with it.[26] In the present study, the effects on line bisection judgements of full field leftward and rightward moving backgrounds were compared with those obtained with both stationary and neutral backgrounds.

In addition to examining the effects of background movement per se, we also wished to determine whether patients with left unilateral spatial neglect were differentially susceptible to the direction of background motion. Several studies have documented a selective rightward attentional bias in patients with left unilateral spatial neglect to static visual stimuli.[30–33] The effects on focal attention of peripheral movement across the visual field, however, is yet to be elucidated. There is strong psychophysical evidence in normal subjects that spatial attention is selectively "bound" to moving objects, and that this binding may take precedence over static, location specific visual cues.[34] If the mechanisms underlying such effects remain intact in patients with left unilateral spatial neglect, rightward background motion may increase the extent of rightward bisection errors. By contrast, leftward motion may reduce or eliminate the patients' impairment in disengaging and shifting attention toward the "neglected" side, thereby changing the extent (and possibly the direction) of bisection errors.

Materials and methods

SUBJECTS

Eleven patients with unilateral damage to the right hemisphere and 11 sex and age matched healthy controls participated. The table gives the age, sex, and clinical details for the patient group.

Lesion location was inferred from clinical examination and confirmed by cranial CT. Patients were screened for gaze disturbances, and visual fields were examined by confrontation testing. Patient 11 had a bitemporal hemianopia after removal of a pituitary adenoma. The mean (SD) age of the patient group was 51·0 (12·9) years, and that of controls was 53·5 (14·2) years (F (1,20) = 0·180, NS). All subjects were assessed as being right handed from their performance on a 10 item questionnaire.[35] Patients exhibited normal sensory and motor function in their preferred (ipsilesional) upper limbs. They were deliberately selected to be relatively heterogeneous (wide ranging) in terms of their performance on standard clinical tests of unilateral spatial neglect (see later), so that we could examine the extent to which the magnitude of any motion effects may have been correlated with the severity of deficits shown on clinical measures.

Patient details and clinical test performance

Patient	Age	Sex	Poststroke	Lesion	VFA	Clinical tests AL	CC	SC	LB
1	69	M	7	(MCA)	NAD	0/0	0/0	0/0	3
2	47	F	4	S(MCA)	LHH	0/6	0/0	30/22	5
3	42	M	8	FTP	NAD	0/0	10/10	7/26	0
4	62	M	5	PT	LHH	100/6	40/0	100/44	38
5	32	F	13	FTP	NAD	0/11	30/0	74/30	–19
6	31	F	2	S	LSQ	0/0	10/0	19/0	–1
7	49	M	13	PS	NAD	0/0	0/0	4/15	–1
8	63	M	4	TP	NAD	39/0	0/0	0/11	2
9	57	M	17	FP	LHH	11/6	10/0	15/15	4
10	64	M	10	PT	NAD	6/33	30/10	33/7	12
11	45	M	13	FS	BTH	100/22	70/0	78/19	23

Cancellation test performances (AL, CC, SC) are expressed as percentage omissions in left and right halves. Poststroke = time of testing (weeks); VFA = visual field assessment; MCA = middle cerebral artery territory; F = frontal; P = parietal; T = temporal; S = subcortical; LHH = left homonymous hemianopia; NAD = no abnormalities detected; LSQ = left superior quadrantanopia; BTH = bitemporal hemianopia; AL = Albert lines; CC = circle cancellation; SC = star cancellation; LB = line bisection (error in mm).

TESTING FOR UNILATERAL NEGLECT

Patients completed a standard clinical protocol before participating in the main experimental investigation. Each patient was given a line cancellation task,[36] a circle cancellation task,[37] and the star cancellation task from the behavioural inattention test.[38] Patients were also given a line bisection test, consisting of 10 horizontal lines varying in length from 80 to 170 mm in 10 mm increments. These lines were centred on a single sheet of A4 paper in pseudorandom order, and drawn through a white cardboard mask with a central window that exposed one line at a time. Deviation from the true midpoint of each line was measured to the nearest mm. Each task was placed directly in front of the patient and centred at the body midline. Patients used their preferred (ipsilesional) hands to hold the pencil. The table shows the percentage of omissions in the left and right halves of each cancellation task, and mean bisection error (in mm).

APPARATUS

All aspects of stimulus production and response recording were controlled by a Toshiba 3100SX laptop computer. Stimuli were displayed on a VGA monochrome screen with an active area of 148 mm (height) × 198 mm (width). Stimuli appeared amber on a black background. The active display was surrounded by a grey plastic border which bore no extraneous marks that could be used by subjects as cues. Bisection judgements were made via a response box, into the top of which were mounted two horizontally adjacent microswitches (48 mm separation), capped with plastic buttons. These were used to control the position of the display cursor. A third microswitch was mounted in the centre of the front panel of the response box, which allowed subjects to record their response and initiate the next trial.

PROCEDURE

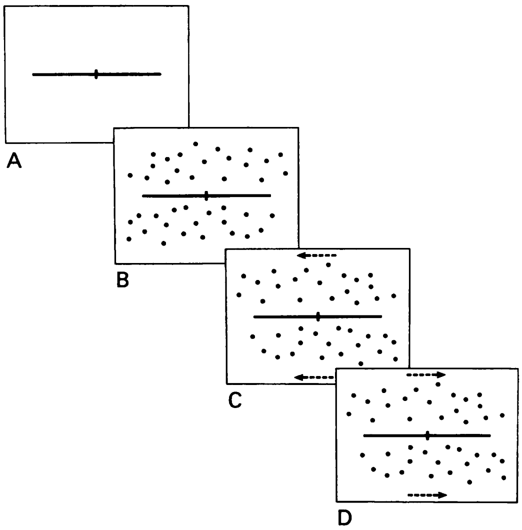
Control subjects and most patients sat at a table throughout the experiment, with the display located at a distance of about 450 mm and aligned with the body midline. Some patients were tested while sitting upright in bed, with a height adjustable table located at a comfortable distance in front of them. The response box was located to the right of the display, so that subjects could use their ipsilesional hands to operate the buttons.

At the beginning of each trial, a solid, horizontal line (2 mm thick) was presented individually in the centre of the display, with a vertically oriented cursor (1 mm width × 8 mm height) located at either the left or right end. Subjects moved the cursor leftward or rightward (using appropriate buttons on the response box) toward the perceived midpoint of the line. Depressing the left side button moved the screen cursor leftward, and depressing the right side button moved it rightward. Velocity of cursor movement was set at 20 mm/s for both patients and controls. The computer recorded the horizontal distance of the cursor from the true midpoint of the line to an accuracy of 1 mm. The task was self paced, and subjects were free to correct perceived errors until they were satisfied. No feedback was provided on accuracy.

On initiation of each trial, the computer displayed the line with one of several different backgrounds. There were two baseline conditions, one in which the background remained blank, and the other in which a stationary, spatially random array of solid circular dots (4 mm diameter) was displayed over the active area of the screen. The density of dots remained constant at 40 per screen, 20 appearing above and 20 below the centrally displayed line. In the remaining two conditions, the background dots drifted across the screen at a constant velocity, either leftward or rightward, disappearing on one side of the display and re-emerging on the other. Figure 1 shows the four different display conditions. The spatial locations of dot stimuli were randomised by the computer for successive trials in the stationary and moving background conditions. It is important to note that dots appeared only in the regions above and below the narrow horizontal band of the display that contained the stimulus line and cursor. Thus there was no contiguity between the central line stimulus and the peripheral background.

Two line lengths (140 and 180 mm) were used to reduce the likelihood of subjects developing a response bias. Bisection errors for these two line lengths were combined for

Figure 1 Display conditions used in the experiment (cursor is shown in centre of horizontal line). (A) neutral background; (B) stationary background; (C) leftward background motion; (D) rightward background motion.



purposes of analysis. The factors of interest were side of cursor start (left or right) and type of background (absent, stationary, leftward movement, and rightward movement). In the two moving background conditions, there was an additional nested factor of movement speed (40 or 80 mm/s). Thus there were 12 conditions, each involving eight lines (four of each length), making a total of 96 lines per subject. Stimuli were presented in four blocks, each containing 24 stimuli (two line lengths × 12 conditions) in a different pseudorandom order. The order of blocks was counterbalanced between subjects.

Subjects were given a set of practice trials in order to become familiar with the task. They were instructed to move the cursor to the midpoint of the line, ignoring as far as possible any background stimuli. When satisfied with their placement of the cursor, they pressed the appropriate button to record their judgement. Patients were required to demonstrate during practice trials that they were competent in locating and operating both response buttons.

The display remained blank between successive trials. In pilot testing, it was established that even prolonged exposure to the moving background stimuli did not cause optokinetic nystagmus. Subjects were also monitored during the experiment, however, to ensure that optokinetic nystagmus was not induced. Horizontal eye movements were monitored by the examiner, who sat opposite the subject behind the computer display. After completing a trial, subjects would occasionally be asked to maintain fixation on the examiner, who checked for irregular eye movements. These are normally characterised by a slow phase in one direction, and a fast return or compensatory phase in the opposite direction.[39]

Results

EFFECTS OF STATIC AND DYNAMIC CUEING

In the first set of analyses, data were collapsed across the factor of movement speed for each subject group. We examine the effects of this nested factor in the next section. Signed (leftward: negative, rightward: positive) bisection errors were submitted to a three way analysis of variance (ANOVA) with group (patients, controls) as a between subjects factor, and cursor start (left, right) and background (absent, stationary, leftward movement, rightward movement) as within subjects factors. All main effects and interactions from this analysis were significant ($p < 0{\cdot}05$ or better).

Two further analyses were therefore conducted separately on data from each subject group. Analysis of control data showed a significant main effect of cursor start ($F\,(1,10) = 5{\cdot}042$, $p < 0{\cdot}05$) and a significant two way interaction of cursor start by background ($F\,(3,30) = 7{\cdot}297$, $p = 0{\cdot}001$). To further explore the nature of this interaction, separate analyses were performed for each cursor start position. Background variables significantly affected bisection judgements in the left cursor start position ($F\,(3,30) = 3{\cdot}303$, $p < 0{\cdot}05$) but not in the right cursor start position ($F\,(3,30) = 2{\cdot}336$, $p > 0{\cdot}05$). Post hoc analyses (Tukey's, $\alpha = 0{\cdot}05$) showed that, in the left cursor start position, mean bisection error with the leftward moving background ($-0{\cdot}5$ mm) was marginally to the left of that with the stationary background (0·3 mm). There were no significant differences in remaining comparisons.

By contrast, the patient group was highly susceptible to background conditions. A two way ANOVA conducted on the patients' bisection errors showed significant main effects of cursor start and background, in addition to a significant interaction between these factors ($F\,(3,30) = 3{\cdot}553$, $p < 0{\cdot}05$). This interaction was explored further by analysing separately the bisection errors from each cursor start position. Background type had a significant effect on bisection errors in both left cursor start ($F\,(3,30) = 4{\cdot}411$, $p < 0{\cdot}05$) and especially in right cursor start ($F\,(3,30) = 15{\cdot}442$, $p < 0{\cdot}001$) conditions. In the left cursor start conditions, post hoc tests showed that mean bisection error with the leftward moving background ($-4{\cdot}2$ mm) was significantly further from (and to the left of) the true midpoint than with the stationary background (3·5 mm) or rightward moving background (4·1 mm), where in both cases the transection lay to the right of centre. There were no significant differences between remaining means. Similar results emerged from the right cursor start conditions, with post hoc tests showing that mean bisection error with the leftward moving background ($-16{\cdot}5$ mm) was significantly further to the left of the true midpoint than with the background absent ($-5{\cdot}8$ mm), stationary ($-3{\cdot}0$ mm), and moving rightward (0·9 mm). There were no significant differences in remaining comparisons.

Figure 2 shows the mean bisection error, plotted separately for left and right cursor start, as a function of background type. This figure indicates that leftward background movement shifted patients' bisection errors leftward, regardless of cursor start position, when compared with the other background

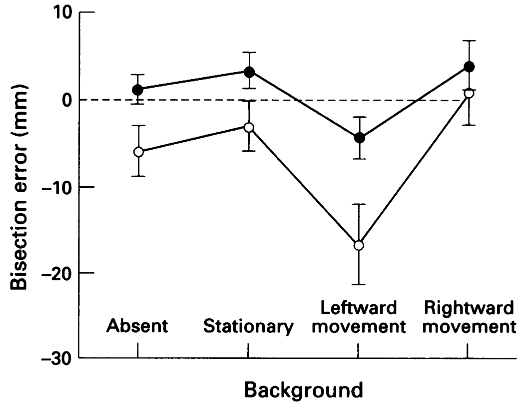


Figure 2 Mean (SEM) bisection error for the patient group as a function of background condition. Filled circles: left cursor start; open circles: right cursor start.

conditions. By contrast, rightward background movement did not alter patients' bisection errors when compared with the background absent and stationary conditions.

To summarise, the results suggest that errors made by normal controls on a horizontal line bisection task were only minimally affected by leftward background motion with a right cursor start. By contrast, bisection errors made by the patient group changed substantially in the presence of leftward motion, regardless of cursor start position, when compared with errors in the stationary and rightward moving background conditions. Bisection errors with a rightward moving background, however, did not differ from those obtained in the neutral and stationary background conditions.

EFFECTS OF BACKGROUND MOVEMENT SPEED

A separate four way ANOVA was conducted to examine the effects of background movement speed on bisection performance, with group (patients, controls) as a between subject factor and cursor start (left, right), background movement (leftward, rightward), and speed (40 mm/s, 80 mm/s) as within subject factors. We report here only those results that include the factor of movement speed, as all other factors were dealt with in the previous analyses. In view of the significant three way interaction of group by cursor start by speed ($F(1,20) = 7{\cdot}293$, $p < 0{\cdot}05$), separate two way ANOVAs were conducted on data from each subject group to determine the nature of this highest order interaction.

For controls, there was a significant main effect of speed ($F(1,10) = 5{\cdot}367$, $p < 0{\cdot}05$), indicating that mean bisection error was slightly further to the left of the true midpoint with the faster (−0·8 mm) than with the slower moving background (−0·6 mm). In the absence of any significant interactions, this result was not considered further.

For patients, there was a significant two way interaction of cursor start by speed ($F(1,10) = 7{\cdot}036$, $p < 0{\cdot}05$). Separate one way ANOVAs conducted on data obtained in the two cursor start positions indicated that mean bisection error did not change as a function of speed in the left cursor start condition ($F(1,10) = 1{\cdot}449$, $p > 0{\cdot}05$). By contrast, when the cursor started on the right, mean error was significantly further to the left of the true midpoint with the slower moving background (−10·3 mm) than with the faster moving background (−5·3 mm) ($F(1,10) = 8{\cdot}889$, $p < 0{\cdot}05$).

RELATION BETWEEN CLINICAL TEST PERFORMANCE AND SUSCEPTIBILITY TO BACKGROUND MOTION

Whereas there are several clinical variables that may account for the different performances by patients on the line bisection task (for example, chronicity and locus of lesion, presence of visual field defects), it seems at least intuitively plausible that those patients with severe neglect on clinical tests might be more susceptible to the attentional modulation elicited by background motion than those with less severe symptoms. We therefore used a correlation matrix to compare patients' performances on each of the clinical measures of neglect severity, with the magnitude of their bisection errors in the two moving background conditions. To reduce the likelihood of type I error, a conservative criterion for significance ($a = 0{\cdot}01$) was adopted. Although there were some significant correlations between clinical tasks, there were no significant correlations between these and patients' bisection errors in the presence of leftward or rightward motion. Even at $a = 0{\cdot}05$, there was only one, marginally significant, correlation between freehand line bisection and leftward background motion with a left cursor start ($r(9) = -0{\cdot}69$).

Although the group analyses provided important information on common features, an examination of the susceptibility of individual patients to the effects of peripheral background movement showed a very heterogeneous pattern of bisection errors. Figure 3 shows the effects of background movement on judgements made by individual patients. Mean bisection error in the stationary background condition has been subtracted from error in the leftward and rightward moving background conditions, thereby providing a relatively pure index of the influence of peripheral background movement.

Several individual performances are worthy of particular mention. Patient 10 showed severe left unilateral spatial neglect on standard clinical measures (see table), and was highly susceptible to the effects of background movement. By contrast, patient 1 was virtually unimpaired on clinical measures of neglect severity and was not susceptible to the effects of background movement. Such cases suggest that the two types of task (clinical and experimental) might measure a single dimension of impairment. There were, however, at least two patients whose performances on clinical and experimental tasks were clearly dissociated. For example, patient 11 showed very severe left neglect on clinical measures, but was unaffected by background movement. By contrast, patient 6 performed within normal limits on clinical tasks, but was clearly affected by both leftward and rightward moving backgrounds. The performances of patients 6 and 11 underscore the earlier

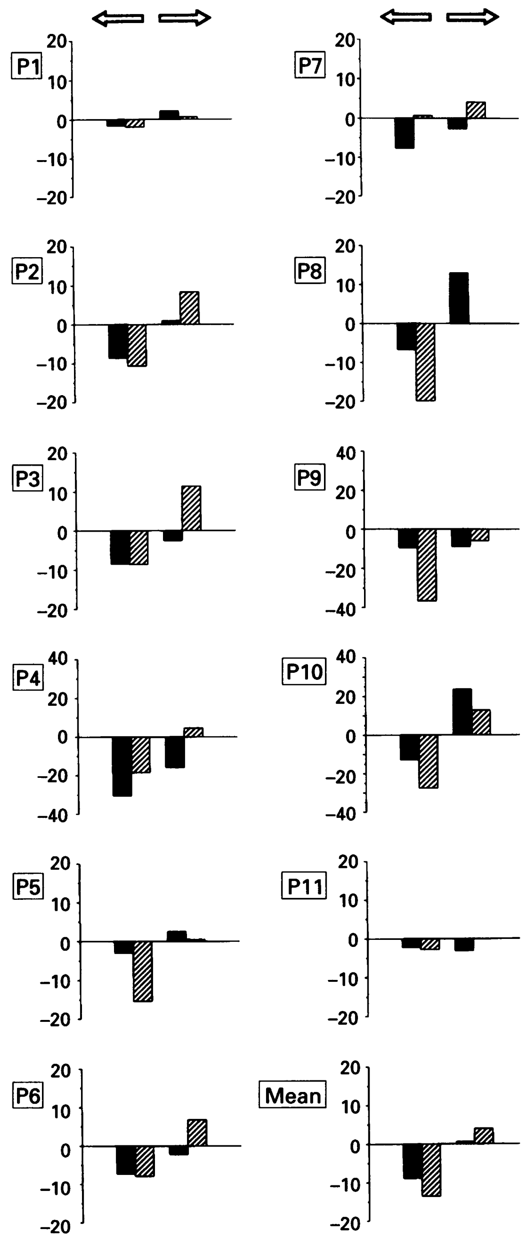


Figure 3 Effects of background motion on line bisection judgements (mm) of individual patients. Arrows indicate the direction of background motion (leftward or rightward). Solid bars: left cursor start; hatched bars: right cursor start. Group means are presented in the bottom right panel. Note change in vertical scale for patients 4, 9, and 10.

suggestion that standard clinical tasks seem to index attentional deficits that are essentially different from those measured in our experimental paradigm.

Discussion

The present results provide compelling evidence that spatial judgements made by patients with left unilateral spatial neglect may be affected by global motion in a background stimulus array. Although there was some evidence that healthy controls were also marginally influenced by background movement, this effect was limited to leftward motion with a left cursor start. This finding is consistent with evidence from studies with chronometric performance indices, which show that common motion may exert an influence on normal attentional processes.[21,22] The fact that these errors were very small, however, suggests that normal controls were performing at ceiling level in our task, which involved self paced judgements on a limited spatial scale.

By contrast, patients showed strong and consistent effects of moving background stimuli, which occurred independently of static cues provided by cursor starting position. Thus regardless of whether patients were required to move the cursor from the left or right end of the line, a leftward moving background significantly shifted bisection judgements toward the "neglected" (left) side in comparison with the stationary and rightward movement conditions.

The effects in patients of leftward background motion cannot be attributed to the relative spatial positions of the response buttons used to control cursor movement. All subjects were required to demonstrate during practice trials that they were competent in locating and operating both response buttons. More importantly, however, the motor demands of button pressing remained constant across all background conditions, thereby avoiding the possibility of any systematic motor bias. Instead, we propose that activation of motion detection mechanisms provides an additional source of input to a distributed attentional network.[40] When the allocation of focal attention is disrupted, as in patients with unilateral spatial neglect, preserved motion processing mechanisms may be exploited to assist in directing focal attention to otherwise "unattended" regions of visual space.

Although the presence of static visual stimuli in the ipsilesional periphery has been shown to exacerbate the attentional deficit in patients with unilateral spatial neglect,[41,42] in our study only patients 6, 9, and 10 exhibited a substantial rightward shift (respectively, 4·5, 7·9, and 7·0 mm) in mean bisection error in the stationary, relative to the neutral, background condition. Thus some patients seem to be more susceptible than others to the presence of static stimuli in the ipsilesional periphery. Also, rightward background motion had no incremental effect (compared with the non-moving backgrounds) on the magnitude of bisection errors. This is consistent with the notion that patients' attention is maximally and chronically biased toward the ipsilesional side.[30,31] For example, in a recent study[33] we found that patients with a damaged right hemisphere and left unilateral spatial neglect in the acute phase of their disorder still continued to exhibit a strong rightward attentional bias after 12 months, even when performance on standard clinical tests had returned to normal. Of course, some patients in the present study (for example, patient 10) were clearly affected by rightward motion, indicating that, in certain patients, focal attention may be yet further biased toward the ipsilesional side.

In the case of leftward background motion, patients bisected lines too far to the left of the true midpoint, a pattern opposite to that which prevails in the standard version of the task. Thus the presence of leftward motion assists in directing attention toward an otherwise "neglected" region of space. This occurs in the absence of any laterally biased cues, and without any explicit demands to shift focal attention toward the left. The use of leftward background motion has clear rehabilitative potential. As visual motion occurs peripherally to the region of focal attention, patients may benefit from its continued presence without the need to first locate and respond to static, left sided visual cues. Rather than requiring patients voluntarily to shift focal attention, the presence of leftward background motion may automatically guide focal attention to the left, a possibility that has been demonstrated previously with dynamic lateralised cues.[25]

The finding of a substantial leftward error is itself also intriguing, as it suggests that leftward motion can in some circumstances induce "ipsilesional neglect", a phenomenon which has been found in standard bisection of very short lines,[43] and in cancellation[44] and target identification[45] tasks. It has been suggested that the right hemisphere controls attention in both left and right hemispace, and that damage to this hemisphere therefore produces attentional deficits in both sides of space.[44] By helping to shift attentional resources toward the left of the line, leftward background motion may induce an impairment in directing attention ipsilesionally, which is comparable with, although perhaps less severe than, the contralesional impairment exhibited clinically.

The effect of background movement speed in controls was very small, and did not interact with the direction of background motion, or with the laterality of cursor start. In patients, larger leftward bisection errors were obtained with the slow, compared with the fast, moving background, but only with a right sided cursor start. These results confirm that the moving background did not induce optokinetic nystagmus. If this had occurred, patients would have shown larger bisection errors with fast background motion, which was closer to (though still well below) the speed used to induce optokinetic nystagmus[26] (about 500 mm/s). The combination of brief durations of exposure and relatively slow motion used here ensured that the effects on line bisection judgements were not produced by optokinetic nystagmus.

The results of correlational analyses also showed that the extent to which patients were susceptible to the effects of background motion was not related to the extent of impairment shown on standard clinical tests. With respect to performances on such tests, our patient group was deliberately heterogeneous, a fact that renders the finding of significant leftward background motion effects even more compelling. It is clear that even relatively subtle changes in stimulus properties and task demands may substantially alter performance in such patients.[46]

An apparently anomalous finding was that bisection errors made by patients in the right cursor start conditions were to the left of those made with a left cursor start. This effect seemed to be related to the presence of a moving cursor that was itself especially demanding of focal attention, because subjects had to visually track its progress across the stimulus line while simultaneously judging its distance from either endpoint. In the case of patients with a damaged right hemisphere, it is known that there is a tendency for attention to be narrowly focused,[47] a phenomenon which may itself stem from the predisposition of the intact left hemisphere to engage in feature based, rather than global, analysis of stimulus arrays.[48] Indeed, the task of horizontal line bisection in particular has been suggested to induce further constriction of an already narrow attentional focus in patients with left unilateral spatial neglect.[49]

It is therefore possible that, in our paradigm, patients focused their attention on the moving cursor and did not detect the endpoint of line stimuli until relatively late in the cursor's trajectory. Under these circumstances, a right cursor start (leftward cursor movement) could result in an error to the left of the true midpoint, whereas a left cursor start (rightward cursor movement) could result in an error to the right of the true midpoint. This is precisely the pattern of results obtained in the neutral and stationary background conditions, in which motion cues were absent.

This explanation also received anecdotal support from our findings on several patients who occasionally moved the cursor across the entire length of the line and off the display. Interestingly, this occurred almost exclusively with a right cursor start—that is, leftward cursor movement—suggesting, at least in some patients, the existence of an impairment in shifting focal attention leftward from the cursor to the left endpoint of the line. In these instances, patients typically seemed perplexed, often claiming that the cursor had "disappeared", but remaining unaware that they had simply moved it beyond the edge of the screen. In any case, regardless of these cursor effects, the patient analyses showed unequivocally that left horizontal motion exerts an effect that transcends such strong demands on focal attention.

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