Triangular backgrounds shift the bias of line bisection performance in hemispatial neglect

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Objective: Patients with left neglect on line bisection show normal implicit sensitivity to manipulations of both the stimulus and the visual background. Three experiments were designed to define this sensitivity more exactly.

Methods: Normal controls and patients with left neglect performed a series of horizontal line bisection tasks. Independent variables were the configurations of the backgrounds for the line—rectangle, square, circle, left and right pointing isosceles triangles—and whether the background was the shape of the piece of paper or an outline drawn on a standard piece of paper. In a separate experiment different components of the triangle were outlined on a piece of paper. Deviation from true midpoint was calculated.

Results: Simply placing the target lines in a symmetric background such as a square or circle did not reliably reduce neglect. A triangle asymmetric in the horizontal plane caused a shift in bisection away from the triangle’s vertex. With right pointing triangles the perceived midpoint shifted to the left of true centre (crossed over). The effects of the triangles were comparable in the patients and the controls when controlled for baseline bisection bias. The critical components of the triangles were the angular legs. This effect of background was not influenced by lesion site or by hemianopia.

Conclusions: Patients with left visual neglect remain sensitive to covert manipulations of the visual background that implicitly shift the perceived midpoint of a horizontal line. This effect is strong enough to eliminate neglect on a bisection task. The mechanism of this effect is expressed through preattentive visual capacities.

Patients with hemispatial neglect after right hemispheric damage fail to report or respond explicitly to stimuli appearing in the left hemispace. Bisection of horizontal lines is commonly used at the bedside to detect neglect, and right hemispheric damage results in displacement of the mark to the ipsilateral (right) side. This phenomenon is deceptively simple, as it can be dramatically influenced by many properties of the stimulus (the length of the horizontal line), the background (the page), the visual field in which the task is presented, and the context in which the stimulus appears.

The length of the line is positively correlated with the extent of rightward bias. Very short lines can produce a “crossover” effect in which the line is bisected left of the actual midpoint despite a right sided lesion. Whatever its length, no line stands entirely free of context. Even long lines may be bisected unexpectedly to the left ("crossover") if the immediately preceding line was longer. Altering context by making small changes in line morphology can produce substantial effects on neglect. There are well known perceptual illusions created by adding fins (<<>) to a line’s ends. Both the illusion of length (Muller-Lyer: >><< appears longer than <<>>) and the illusion of perceived midpoint (Judd: >> appears to have a midpoint to the left of the true midpoint) are present in the line bisection of patients with neglect.

The page of paper on which a line is presented is generally considered a passive vehicle, but it too can exert a powerful influence on the extent of bisection displacement. For instance, Marshall and Halligan reported that a patient with severe, persistent neglect evidenced a striking reduction of bisection displacement when the line to be bisected was centred in square or circular pieces of paper. Regular symmetry of the background seemed to affect neglect, as bisection progressively improved as page shape went from rectangle to square to circle. This effect of background is consonant with the same investigators’ previous demonstration that changing the bisection task to marking the centre of a geometric shape also influences neglect. The magnitude of midpoint displacement is inversely related to the "height" of the figure from "flat" rectangle to square or from "flat" ellipse to circle.

In all of the tasks summarised above, the conscious, attention demanding requirement is locating the midpoint of some stimulus, usually a horizontal line. All other aspects of the task that influence performance are thought to be “preattentive”, that is, they utilise operations in visual perception that occur in the absence of directed attention or awareness.

The experiments reported here were motivated by observations about preattentive processing of the context of stimulus and of background information on neglect. We had two goals. Firstly, most of the observations about the effects of background manipulation come from single case studies, often of patients with very severe, and unusually persistent, neglect. For example, the claims about background (paper) shape were made in a patient with left hemianopia in addition to neglect, who, several months after stroke, still had a mean deviation of 60 mm on bisection of 180 mm lines centred in a rectangle. It is not known if these effects are so readily demonstrated in patients with more typical and milder neglect. In the case report, the authors essentially request that such a confirmation be performed.

Secondly, in the studies of Halligan and Marshall, both “height” and “length” of the stimulus figure or the background were manipulated, but all were symmetric about both horizontal and vertical axes. Incorporation of the horizontal bias in the Judd illusion (>>>) into the background should markedly shift midpoint determinations in patients with neglect, just as the simple illusion does in

Abbreviations: TD, transaction displacement.
Table 1  Clinical characteristics of patients with neglect

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age</th>
<th>Sex</th>
<th>Lesion site</th>
<th>Visual field defect</th>
<th>Weeks post-injury</th>
<th>Hemiparesis</th>
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<td>83</td>
<td>F</td>
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<td>6</td>
<td>+</td>
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<tr>
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<td>78</td>
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LHH, Left homonymous hemianopia; LQG, left inferior quadrantanopia; lesion site I, frontal; lesion site II, subcortical/deep; lesion site III, posterior/parietal-occipital.

normal people. Presuming that the direction of the fins shifts perceived midline, then a background of an isosceles triangle with base perpendicular to the stimulus line should have the same directional effect: neglect reduced for right apex triangles and increased for left apex triangles.

We report the findings in a larger sample of patients in three experiments that manipulated background (page) shape (experiment 1: rectangular, square, circular, left triangle, right triangle), outlined shape on paper (experiment 2: left triangle, right triangle), and the outlined shape with different aspects of the triangle eliminated (experiment 3).

EXPERIMENT 1

Subjects
All patients with documented right hemispheric stroke as seen on CT or MRI who were admitted to the inpatient service of an acute rehabilitation hospital were identified. Only patients who spoke English and whose primary physician thought would be able to cooperate during the testing protocol were approached to participate. Patients were excluded from participation if there was a history of stroke, dementia, or any uncorrected visual disturbance (other than hemianopia).

There were 14 patients tested. Clinical and demographic data are summarised in table 1. Duration after stroke onset ranged between 2 to 12 weeks. Most (12) patients had significant left hemiparesis and substantial functional limitation. Five patients had hemianopic field defects to confrontation testing. Most patients had large lesions involving multiple right sided structures. Seven had frontal lesions, but only two were relatively isolated. Eleven had significant deep, lenticulostriate lesions, not surprising in a population in acute rehabilitation with hemiparesis, but only four were relatively isolated. Seven had posterior damage, but only one was isolated.

Thirteen right handed age and sex matched control participants were also included. The mean age of the control group was 68 years (SD 13.0; range 43 to 77). All control participants were without history of neurological or eye disease.

Procedure
The method was designed to attempt to replicate the findings of Marshall and Halligan. Participants were asked to bisect a total of 50, 7 inch (17.8 cm) horizontal lines that were drawn on different shaped pieces of paper. There were 10 trials each in which the lines were centred on rectangular sheets of white 9x12 inch paper, on square sheets of paper (12 inch sides), on circular sheets of paper (diameter 12 inches), and on isosceles triangular sheets of paper (axis 12 inches)—with the base of the triangle positioned perpendicular to the horizontal line target and the vertex pointed to the left or right (fig 1).

The 10, 7 inch horizontal lines centred within the rectangular sheets of paper were used as a baseline measure of bisection error. Based on the Halligan and Marshall report, this condition should have produced the most severe bisection error. It was reasoned that if a patient showed minimal error in this condition, there would likely not be enough “room for improvement” to evaluate the potential beneficial effect of the square and circle (and triangles). A mean deviation of 4 mm to the right was chosen as a minimum bisection error in order for patients to be administered the remaining context conditions. Four millimeters was chosen somewhat arbitrarily based on previous line bisection tasks in which we have shown that normal control participants rarely, if ever, produce deviations greater than 4 mm with a 7 inch line.

Each laminated stimulus sheet of paper was presented separately and always positioned on a tray top draped with a grey cloth in front of the subject so that the objective midpoint lay in the sagittal midplane of the subject’s trunk. The order of the shaped pages was pseudorandomised so that no more than three trials of a particular shape were presented successively. Responses were made with a fine pen with erasable ink held in the right hand. Transsection displacement from the true
midpoint was measured to the closest millimeter and expressed as + for rightward and – for leftward bias.

**Results**

The mean deviation from the true midpoint is provided in figure 2 for patients with hemispatial neglect and controls. Analysis of variance (ANOVA) indicated main effects of group ($F(1,25)=38.44$, $p<0.001$), shape ($F(1,25)=38.44$, $p<0.001$), and a significant interaction between shape and group ($F(4,100)=19.41$, $p<0.001$). Post hoc comparisons showed that line bisection performance was not significantly influenced by page shape for rectangles, squares, or circles for either the control group or the patient group (all $p$ values >0.05). There was a significant difference between line centred in the triangle. There were 10 trials of left pointing triangles and 10 trials of right pointing triangles (fig 1).

**Method, experiment 2**

Isosceles triangles were drawn on a laminated 18×24 inch sheet of white paper, and subjects were asked to bisect a 7 inch line centred in the triangle. There were 10 trials of left pointing triangles and 10 trials of right pointing triangles (fig 1).

**Results**

Transsections from the triangular sheets of paper from experiment 1 were compared with the transsections of the outlined triangles from experiment 2 for the subgroups of patients and controls who performed both. There were no significant differences in the magnitude between experiments 1 and 2, of the lateral shift of bisection for patients, either for triangles pointed right ($p>0.1$) or for triangles pointed left ($p>0.05$), or for controls ($p>0.05$). The relative effects of triangular backgrounds seen in experiment 1 were replicated in experiment 2; the point of transsection always shifted away from the vertex towards the base of the triangle.

**Summary, experiment 2**

The isosceles triangle background had an equally potent effect on perceived midpoint of a line whether the background was literally a triangular paper or simply a triangle drawn on conventional paper. In neither case was the shape of the paper or the drawn outline an explicit factor in the instructed task.

**Method, experiment 3**

The outlined triangle was deconstructed by removing either both “legs” of the apex or the “base” of the triangle. Again there were 10 trials each for the six possible outlined shapes (full outlined left or right, “legless” left or right, and “baseless” left or right (fig 1).

**Results**

Eliminating the apex “legs” of either triangle left only the vertical base as a possible lateral cue. Line bisection with only the

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**Figure 2** Mean bisection error (SD) for patients with neglect and controls as a function of shape in experiment 1.
vertical base remaining to either the left or the right was not significantly different from performance with the rectangular shaped background of experiment 1 in either patients or controls (all p values > 0.4). Thus, shift of the perceived midpoint was lost without the vertex. By contrast, in triangles with the base eliminated, patient transactions remained markedly shifted away from the apex comparable to the full triangle (p > 0.3) and significantly different from the baseline rectangle (p < 0.001) (fig 3).

Summary, experiment 3
The vertex angle formed by the “legs” of the triangle is the crucial element that shifts perceived midpoint. With the “legs” of the triangle removed, leaving only the base adjacent to the horizontal line to be bisected, there was no difference in transaction performance compared with our baseline condition (rectangle). The results do not support the hypothesis of Halligan and Marshall that a vertical component to the stimulus or the background could act as a cue and ameliorate neglect.6 However, the gap between the horizontal line and the unconnected vertical base was much greater in our experiment (77 mm) than in theirs (4 mm), perhaps explaining the lack of lateralising cueing in our experiment (fig 3).

DISCUSSION
Our experiments incorporated elements of background effects with elements of line illusions. Not surprisingly, either a background or feature context explanation can account for the potent effect of isosceles triangles.

The background account would be based on implicit—that is, preattentive sensitivity to geometric illusions. The Judd illusion (for example, < − < or > − >) is a shift of perceived midpoint. In both unilateral and bilateral Judd illusions, normal subjects, and patients with neglect7,8 make bisections that are displaced from the objective midline towards the outward projecting fin and away from the inward projecting fin. Stimulus features present in left hemispace that are neglected in explicit tasks, nevertheless influence the shifts in perceived midpoint. In both unilateral and bilateral Judd illusion figures, the stimulus can affect visual neglect in patients with right brain damage has been demonstrated in many ways. The consistent induction of midpoint shift by the triangular background can be added to the list. Most explanations of these phenomena assert that they represent intact preattentive visual processing in the setting of impaired explicit visual attention. Work from our laboratory has specifically demonstrated that patients with hemispatial neglect can perform preattentive parallel searches normally but are impaired on attentive serial search.9–11 Even when no physical response into space is required, such as lexical decision, visual material that is neglected in explicit recognition tasks can still be processed for meaning.12 13

The two accounts presented above presume preattentive processing of information presented in the neglected hemisphere. However, it should be considered whether the observed shifts in perceived midpoint could have been induced by the explicit perception of information available in the ipsilesional space. This possibility cannot be evaluated in the current study, due to the fact that on each trial, the background and stimulus features present in left and right hemispace were deconstructed into partial triangles.14 The triangles were deconstructed into partial triangles.15 The triangles could have either originated from the vertex or base and,
while presented in midline, could have been presented solely in left or right space, in the case of partial triangles (50% or less). Consistent with the current study, the perceived midpoint always shifted toward the base of the triangle. Most relevant to the explicit account being considered here, there were no differential effects between patients with neglect and control participants of the partial triangles when they appeared to the left versus right of midline. There was an overall increase in bisection error to the right when the partial triangles appeared in the left versus the right, but to the same magnitude in both patients and control participants. In other words, the effect of a partial triangle appearing only in the non-neglected side of space was the same across groups as a partial triangle appearing only in the neglected side of space. These findings do not support an account of bisection shifts due only to explicit perception of the portion of triangles appearing in the right, ipsilesional side of space.

The current study, thus provides strong support for preserved preattentive visual processing, as the observed effects were seen in all 14 patients with neglect, mild or severe, with or without coexisting left hemianopia, and with all lesion locations—frontal, posterior, or both. It is certain that preattentive processes of various types are well preserved regardless of the neuroanatomical location of lesions that cause neglect. Halligan and Marshall have repeatedly shown preserved preattentive processes even in patients with extremely severe neglect and complete hemianopia due to extensive occipital infarctions in the right posterior cerebral artery territory. As even the presence of total left hemianopia and severe right occipital damage does not blunt these phenomena, the visual association cortex of either hemisphere must be capable of extracting and processing information without explicit attention or awareness. Although preserved preattentive processing of stimuli in left hemispace has been repeatedly demonstrated, a method to utilise these processes to ameliorate neglect remains elusive.

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REFERENCES