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BRIEF COMMUNICATION

Triangular backgrounds shift line bisection performance in hemispatial neglect: The critical point

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Abstract

Isosceles triangular backgrounds influence line bisection performance in normal control participants and patients with hemispatial neglect. When the triangles are oriented asymmetrically with the vertex in 1 visual field, and the base in the other, the perceived midpoint of horizontal lines within the triangle is shifted towards the base, and away from the vertex. The current study examines this illusion further by systematically varying the extent of the triangle presented. With only fragments of the triangle in the background of the line, the vertex is the critical component driving the illusory shift in perceived midpoint. Patients with neglect and controls are equally sensitive to the illusion. Similar geometric illusions that are also intact in neglect, along with these results, suggest that preattentive, implicit visual processing is preserved in neglect and drives these illusions. (*JINS*, 2002, *8*, 721–726.)

Keywords: Hemispatial neglect, Line bisection, Geometric illusions, Perception

INTRODUCTION

Patients with hemispatial neglect often fail to identify or respond to information in the contralesional side of space on a variety of different tasks. A common clinical task for the assessment of neglect is the bisection of horizontal lines. Patients with left neglect due to right hemisphere lesions misplace their bisections toward the ipsilesional (right) side of the line. The magnitude of bisection error can be influenced by a number of manipulations of either the stimulus to be bisected or the background on which the stimulus appears. For example, bisection error is positively correlated with line length (Halligan & Marshall, 1988). Relatively short lines can produce a crossover effect in which the bisection bias reverses into the contralesional (left) side of the line (e.g., Anderson, 1997; Chatterjee, 1995; Halligan & Marshall, 1993; Marshall & Halligan, 1989).

Several studies have found that context can modulate bisection errors in neglect in several ways (Halligan & Marshall, 1991; Heilman et al., 1993; Marshall & Halligan, 1989). In a study by Halligan and Marshall (1991), bisections of geometric figures revealed that displacement error is inversely related to the "height" of the figure (from "flat" rectangle to square or from "flat" ellipse to circle). Line bisection is also influenced by the placement of various geometric figures around the line; neglect diminishes as the height and overall symmetry of the background figure increased (Halligan & Marshall, 1995). Line bisection performance is also powerfully affected by a background of an isosceles triangle (Shulman et al., 1997). In that study, horizontal lines were placed within isosceles triangular backgrounds that were oriented asymmetrically with the vertex in one visual field and the base in the other. For both patients and controls, triangles that were oriented with the vertex in the left side of space shifted bisections toward the right of the true midpoint, and triangles that were oriented with the vertex in the right side of space shifted bisection to the left of midline.

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In patients with left neglect, left pointing triangles intensified neglect, while the right pointing triangle ameliorated neglect, and often even shifted the perceived midpoint into the left side of space. The shifts in bisection biases were apparent in both patients and controls to a similar degree.

The effect of the triangular background could be the result of an implicit computation of the center of mass, such that the base of the triangle, with a greater mass, shifts the center of mass away from the vertex. A previous study found that center of mass of the visual display significantly influenced visual search performance for patients with hemispatial neglect (Grabowecky et al., 1993). In addition, Heilman and colleagues conducted a study with normal participants and found a center of mass effect in a line bisection task that was greater in the vertical compared to the horizontal plane (Shuren et al., 1997). An alternative explanation might be that patients with neglect remain sensitive to geometric illusions, even when the critical stimulus is in the neglected field. In the Judd illusion (e.g. <-<, >->), line bisection is shifted from the objective midpoint toward the outward pointing fins in normal subjects (Fleming & Behrmann, 1998). With either bilateral Judd figures (as above) or unilateral figures (fin in right or left field), perceived midpoint was shifted to the same extent in both normal subjects and patients with neglect (Mattingley et al., 1995; Ro et al., 1998). With the Muller-Lyer illusions (e.g. <->, >-<), neglect patients perceive lines and features inside the fins (<->) as shorter than those adjacent to the vertex (>-<), even when the feature producing the illusion was presented in the neglected hemispace (Mattingley et al., 1995). The preservation of these perceptual illusions in neglected hemispace implies that sensitivity to the illusion is preattentive and implicit. This is consistent with increasing evidence from a variety of paradigms, such as semantic priming, visual search, and cross field matching, that a great deal of higher level visual processing is intact in the neglected hemispace, and is processed in the absence of focused attention (Berti & Rizzolatti, 1992; Esterman et al., 2000; Ladavas, 1987; McGlinchey-Berroth et al., 1993).

The current study had two goals. The first goal was to replicate the earlier study using the touch sensitive computer display, to enable better control of head position and visual angle. The second goal was to differentiate between the center of mass and the preserved sensitivity to illusions hypotheses to account for the effect of the triangular background. If the full triangle is necessary for the bisection effect, then that would support the center of mass hypothesis, since the full figure will maximally shift the center of mass of the display. On the other hand, if only a vertex was required without the full triangle, then the effect is more likely to be due to an illusion similar to the Judd and Muller-Lyer figures. Because the previous study had determined that the base of the triangle did not influence bisection performance, the actual base line was omitted (< , >) (Shulman et al., 1997).

METHODS

Research Participants

Six individuals diagnosed with left hemispatial neglect were recruited from the Braintree Rehabilitation Hospital in Braintree, Massachusetts, and Youville Rehabilitation Hospital in Cambridge, Massachusetts. As shown in Table 1, 3 patients suffered frontal and parietal damage due to stroke (O.S., J.Y., T.J.). Patient T.S. suffered damage to anterior temporal lobe and basal ganglia. All patients were administered the Standard Comprehensive Assessment of Neglect (SCAN; McGlinchey-Berroth et al., 1996), which includes several copying, reading, cancellation, line bisection and extinction tasks. Each patient showed neglect of left space on at least two of these tasks (see Table 1). All patients were without hemianopia or any primary visual field deficit, as confirmed by a neurologist.

Six healthy adult participants served as control participants for the neglect patients. They were recruited from the Harvard Cooperative Program on Aging and were matched with regard to age ($M = 68.5$) to the neglect patients ($M = 73.7$), $p > .3$. All control participants had no history of neurological disorders, substance abuse or psychiatric illness.

Apparatus

Line bisection displays were administered using a Macintosh Powerbook 3400c and a 43 cm Elo Touchsystems touch sensitive monitor. The software package, Psychlab (Gum, 1992), was used to present picture files on the screen and recorded the exact pixel location at which the participant touched the screen. Responses were made by touching the screen at the location perceived to be the midpoint of the horizontal line. An ophthalmologic chin rest was adjusted to place the subject's eye level at midline and maintain a 30 cm distance from the computer screen.

Stimuli

The stimuli for the current study consisted of a 13 cm horizontal line, centered within portions of an isosceles triangular background. Each line subtended a visual angle of 23.1° (11.55° to the left and right of midline). The full isosceles triangle had a base of 13 cm and legs of 19 cm. The triangle subtended a visual angle of 30.4° horizontally (15.4° to the left and right of midline) and 23.1° vertically (11.55° above and below midline).

The triangular background could appear with the vertex on the left (triangle<) or the right (triangle>). Furthermore, 25%, 50%, 75%, or 100% of the legs of the triangle could be present in the background, and this partial triangle could originate from the vertex or the endpoints (see Figure 1).

The same length line appeared repeatedly in the middle of the computer screen, so the true midpoint never changed from trial to trial. In an attempt to discourage participants

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Table 1. Clinical characteristics of patients

Patient	Lesion site	Age	Post-onset	Clinical manifestations
T.S.	Right basal ganglia, anterior temporal lobe	69	5 weeks	Visual Extinction Line Bisection Line, Letter, Symbol Cancellation Scene Copy
O.S.	Right frontal, parietal, and temporal infarct with caudate nucleus lacune	78	7 weeks	Visual Extinction Line Bisection Cross Copy, Recall Copy Letter, Symbol Cancellation
J.Y.	Right parietal and frontal	79	5 weeks	Visual Extinction Line Bisection Cross Copy, Recall Copy Line, Letter, Symbol Cancellation Scene Copy
T.J.	Right MCA and ACA territories	82	7 weeks	Visual Extinction Line Bisection Line, Letter, Symbol Cancellation Figure Copy
E.C.	Deep right frontal	56	3 weeks	Visual Extinction Line Bisection Cross Recall Copy Letter, Symbol Cancellation Figure Copy Scene Copy
G.C.	Right temporal/parietal	78	4 weeks	Visual Extinction Line Bisection

from touching the same point on every trial, a simple detection task was interspersed between each bisection trial. An 'X' randomly appeared at one of four locations 4.52 cm diagonally from midline (6.0° of visual angle on the horizontal and vertical axes), which participants were instructed to touch.

Procedure

The experiment consisted of 150 randomized display trials. Ten of these displays contained only the line without any background and served as a baseline. Ten trials appeared randomly for each of the remaining 14 conditions. Between each bisection trial, the 'X' appeared, and participants were instructed to touch the 'X.'

Each patient was tested individually in either the hospital or their homes. Control participants were tested at the VA Boston Healthcare System. Participants were instructed to use their index finger on their dominant (right) hand to touch the middle of the horizontal line on each trial. Participants were administered three practice bisections before the start of the experimental task. If more practice was required, another three practice trials were administered.

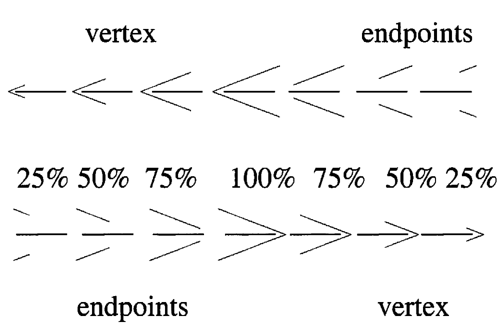

Fig. 1. Triangular backgrounds presented, indicating the orientation of the triangle (triangle$<$ and triangle$>$), what percentage of the triangle was present (25, 50, 75, 100), and whether the partial triangle originated from the vertex or the endpoints.

RESULTS

The primary dependent variable was bisection deviation from the objective midpoint of the line along the horizontal axis, with deviation to the right represented as positive, deviation to the left as negative, and the true midpoint as zero. Deviation is reported in millimeters. Trials were removed if a participant accidentally touched the screen and triggered a response with a different part of their hand or if they unintentionally bisected a piece of the triangle. There were more excluded trials for the patients ($M = 9.50$ trials per patient) than for control participants ($M = 0.17$ trials per participant).

A univariate analysis of variance (ANOVA) was conducted on the mean bisection deviation for each partici-

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pant, with group as a between subjects factor (control, neglect), and triangle type (<,>), percentage (baseline, 25%, 50%, 75%, 100%), and origin (vertex, endpoints) as within subject factors. There was a significant main effect of group [$F(1,10) = 26.64$, $p < .001$] and triangle type [$F(1,10) = 5.19$, $p < .05$]. Neglect patients' line bisections were significantly further to the right ($M = 9.62$ mm, $SE = .57$) than control participants ($M = 1.37$ mm, $SE = .22$). Furthermore, the main effect of the triangle type confirmed that triangle> in the background shifted participant's perceived midpoint significantly further to the left ($M = 4.13$ mm, $SE = .50$) than triangle< ($M = 6.85$ mm, $SE = .62$). The fact that bisection error is small is likely due to the fact that triangle type collapses across all partial triangles derived from the original full triangle.

The ANOVA also revealed significant two-way interactions between Triangle Type × Percentage [$F(4,10) = 8.72$, $p = .0001$] and Triangle Type × Origin [$F(1,10) =$

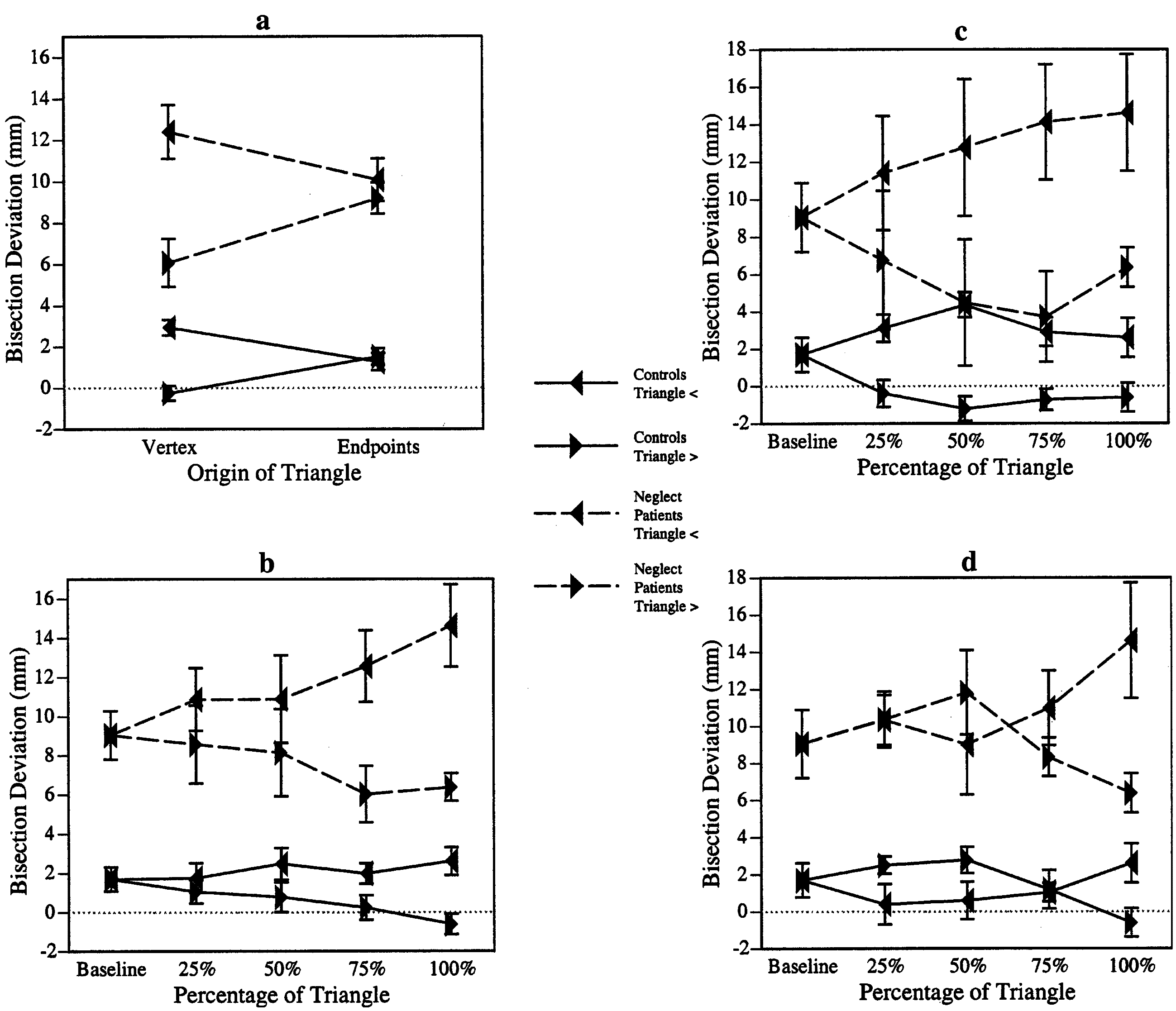

Fig. 2a. (top left). Mean line bisection deviation as a function of triangle orientation and origin of the triangle (vertex *vs.* endpoints), for both patients ($n = 6$) and controls ($n = 6$). This figure demonstrates an increased shift in perceived midpoint to the right for triangle <, and to the left for triangle >, *only* when the vertex was present. Note that positive deviation is to the right of the true midpoint, and negative deviation is to the left.
Fig. 2b. (bottom left). Mean line bisection deviation as a function of triangle orientation and percentage of the triangle presented in background, for both patients and controls. The figure demonstrates an increased shift in perceived midpoint to the right for triangle<, and to the left for triangle> as more of the triangle was presented.
Fig. 2c. (top right). Mean line bisection deviation for triangles with the vertex. The differential effects of triangle orientation appear to be maximized with 50% of the triangle present for controls, and 75% for neglect patients.
Fig. 2d. (bottom right). Mean line bisection deviation for triangles originating from the endpoints. There appears to be little or no differential effect of the triangles on line bisection performance when the vertex is absent (25–75%).

5.39, $p < .05$]. The interaction between Triangle Type × Origin revealed that for both patients and controls, triangle< and triangle> differentially influenced perceived midpoint when the vertex was present ($p < .01$) and not when the triangle contained only the endpoints (see Figure 2a). The Triangle Type × Percentage interaction demonstrates that the effect of triangle type increased as more of the background was presented, such that significant differences between the triangle< and triangle> did not occur with 25% of the triangle ($p > .08$), but did occur with 50%, 75%, and 100% (ps $< .01$; see Figure 2b).

These two-way interactions were further qualified by a significant three-way interaction between Triangle Type × Percentage × Origin [$F(4,10) = 4.59$, $p < .01$]. Figure 2c shows the effect of the partial triangular backgrounds with the vertex present, for both patients and controls. This interaction suggests that with 50% of the triangle, the shifting of the perceived midpoint is maximized for control participants, for whom the effect is even present with only 25% of the triangle. For neglect patients, the shifting of perceived midpoint is present with 50% of the triangle, and appears to be maximized with 75%. In contrast, Figure 2d illustrates that when the partial triangle contains the endpoints and not the vertex, there are no differential effects of triangle type until 100% of the triangle is present (when the vertex *is* present).

DISCUSSION

This study sought to further examine the effects of a triangular background on line bisection in patients with hemispatial neglect and control participants, and to adapt the paradigm from a paper-and-pencil task to a touch sensitive computer screen. Results replicated the original finding that isosceles triangular backgrounds shifted perceived midpoint toward the base and away from the vertex (Shulman et al., 1997). The presence of a vertex was critical to demonstrate the effect. The whole triangle was not necessary to induce the illusion. With only half of the triangle present, the effect was apparent in both patients and controls, providing it included the vertex. Without the vertex, even 75% of the triangular background did not change the perceived midpoint from baseline.

The results of this study do not support the hypothesis that implicit computation of the center of mass of the display determines the effect. The vertex appears to be the critical component of the triangle. The presence or absence of a vertex should not influence estimates of center of mass directly, however closure of the triangle may be an important component that makes the center of mass estimate more salient. Nevertheless, a center of mass hypothesis would support an incremental effect of the triangular background (from 25–100%), with the full triangle exerting the greatest influence on the perceived midpoint. With the vertex present, perceived midpoint is maximally shifted with 50% of the triangle for controls, and 75% for neglect patients, which is again inconsistent with the center of mass hypothesis.

We propose that the effect is due to a geometric illusion similar to the effect of the Judd figure. The end of the line inside the fin is perceived as shorter, and thus, the perceived midpoint is shifted away from the vertex. This is also similar to the Muller-Lyer figure in which lines inside the fins (<->) are perceived as shorter than outside (>-<). The relative effect of the illusion did not differ between patients and control, allowing for the main effect of group, such that neglect patients' bisections were overall shifted to the ipsilesional side of space (right). The fact that neglect patients displayed normal sensitivity to the triangular backgrounds is consistent with the finding of Shulman et al. (1997), further suggesting that implicit, preattentive mechanisms are likely intact in neglect.

The account above presumes preattentive processing of information presented in the neglected hemispace. However, it should be considered whether the observed shifts in perceived mid-point could have been induced by the explicit perception of information available in the ipsilesional space. While there was an overall shift in perceived midpoint to the right when the partial triangles appeared to the left of midline compared to when they appeared to the right of midline, this difference was the same magnitude in patients and controls. 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.

Further research is necessary to determine if the effect of the triangular background extends to tasks other than line bisection, such as reading and visual search. These findings underscore the potential for using preserved preattentive mechanisms in neglect to help patients compensate for their attentional impairments without explicit instructions.

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