ORIENTATION BIAS IN UNILATERAL NEGLECT: REPRESENTATIONAL CONTRIBUTIONS

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ABSTRACT

Left-neglect patients bisect horizontal lines to the right of true center. Longer lines are bisected further to the right than shorter lines. This line-length effect might be explained by an increase in the rightward bias of attention because longer lines extend further ipsilesionally. Alternatively, neglect patients might be limited in their abilities to internally represent horizontal magnitudes. Patients might orient further rightward with longer lines because these lines have longer representations. If the line-length effect occurs on lines of identical objective length but they are represented differently, then central mechanisms must contribute to the orientation bias. We constructed two types of lines that were perceived by normal subjects as having different lengths, but were of identical extents. Three neglect patients bisected lines perceived as longer, further to the right than lines perceived as shorter. These results demonstrate that relative magnitudes of internal representations contribute to the degree of bias in neglect patients.

Key words: attention, unilateral neglect, line bisection, visual illusion, internal representation

INTRODUCTION

Patients with left neglect tend to bisect horizontal lines to the right of true center. This abnormal bias is one of many manifestations of 'unilateral spatial neglect', a neurological syndrome in which patients fail to orient towards, attend to, or act on stimuli located in contralesional space (Heilman et al., 1985). Unilateral neglect is generally considered to be a deficit of higher level cognitive mechanisms (attentional, intentional or representational), and is not explained by deficits of early visual processing (i.e. elementary feature extraction, pre-attentive parsing and grouping of elements in the visual scene).

Line bisection tasks are used frequently to assess unilateral neglect. The rightward errors reflect the rightward orientation bias in these patients. The length of the lines patients bisect has a systematic influence on the magnitude of this bias. Longer lines are bisected further to the right than are shorter lines (Bisiach et al., 1983; Chatterjee et al., 1994; Marshall and Halligan, 1990; Riddoch and Humphreys, 1983). An obvious explanation for this line-length effect would involve how spatial locations of stimuli influence attention. Attention is drawn further rightward with longer lines because these lines extend further into ipsilesional space. As a matter of convention, we will refer to this

explanation as an 'external' account. The critical variable is the horizontal location of stimuli in external space. We contrast this external account with what we will refer to as an 'internal' account. According to this account, patients may be limited in their capacity to internally represent stimuli. Longer lines evoke longer representations. If patients can only maintain a limited horizontal representation, then they would orient further rightward in external space. These external and internal accounts are by no means mutually exclusive.

In the present study, we wished to learn if the internal account could contribute to the line length effect. We used stimuli, which give the illusion of different horizontal extension without being different objectively. Neglect may be susceptible to visual illusions (thought to be generated by pre-attentive processes) arising from both sides of the space (Vuilleumier and Landis, 1998). Some neglect patients line bisections are influenced by the Müller-Lyer illusion (Mattingley et al., 1995; Ro and Rafal, 1996). However, for our purpose this illusion is not useful. For the lines that seem longer in the Müller-Lyer illusion, the 'fins' extend further into ipsilesional space than they do in the lines that appear shorter. Consequently, the external and internal accounts would predict worse bisections with the lines that appear longer.

Using principles underlying the Oppel-Kundt illusion (Suzuki and Arashida, 1992), we constructed two types of lines that occupy the same physical horizontal extent, but are perceived as having different lengths. The Oppel-Kundt illusion refers to the observation that a subdivided spatial interval appears more expanded than an empty space interval of the same length. We constructed two types of lines that were made of relatively long or relatively short segments. We expected that lines made of shorter segments would appear more expanded than lines made of larger segments.

If we demonstrate that these lines produce the illusion of having different lengths, then we can test the internal account directly. If the line length effect were due only to external influences on attention, then there would be no differences in bisection errors between these types of lines, since they extend identically in external space. On the other hand, if an internal account contributes to the line-length effect, then patients should make greater errors on lines comprised of shorter segments, since they have greater horizontal extension in representational space.

Experiment 1: Line Length Judgement

This experiment was designed to test the prediction that lines made of shorter segments are perceived as longer than lines made of longer segments.

Materials and Methods

Subjects

Eight normal subjects (4 males and 4 females) with a mean age of 29 years (SD = 4.81) and educational level of 20.6 years (SD = 3.00) participated in the experiment. Six of the subjects were right-handed and two (1 male and 1 female) were left-handed.

Stimuli and Procedure

Stimuli consisted of pairs of horizontal lines 185, 189, and 200 mm long and 1 mm wide. Each line was centered on an 8.5 × 14 inches (215.9 × 355.6 mm) sheet of white paper oriented horizontally. Lines were made of segments with two different ranges. Stimulus A consisted of lines with segments ranging from 20 to 38 mm. Stimulus B consisted of lines with segments ranging from 3 to 5 mm (see Figure 1). Segments of different lengths were used to prevent a strategy in which subjects might simply count the segments and then bisect the central one in experiment 2. Five different comparisons were made, using these stimuli. The lines were aligned along their horizontal axes, such that one line fell to the right of the subjects' trunk and the other to the left. The left end of the right-sided line and the right end of the left-sided line were separated by approximately 108 mm. The left-sided page overlapped the right-sided page in half of the trials. The overlapping page was counterbalanced within conditions. The pairs of lines, centered on subjects' sagittal midplane, were presented on a table at a distance of approximately 50 cm.

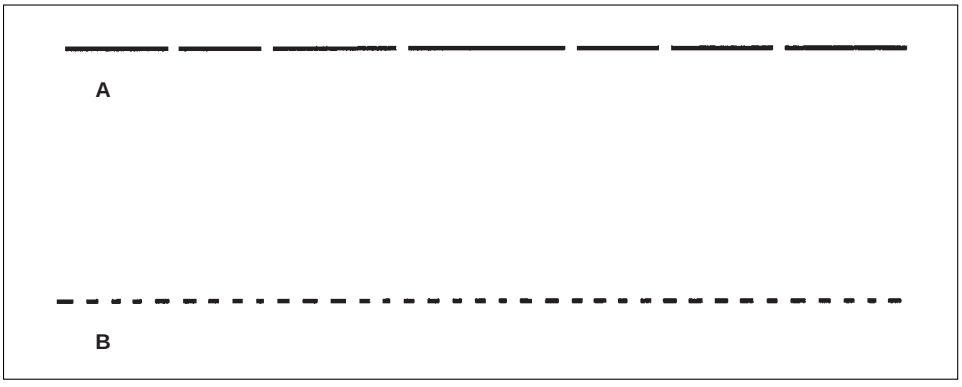

Fig. 1 – *Example of stimuli used in condition A and B.*

Lines 200 mm long, belonging to stimulus A, were compared to lines 189 and 185 mm long, belonging to stimulus B (comparisons 1 and 2). Lines 200 mm long, belonging to stimulus B, were compared to lines 189 and 185 mm long, belonging to stimulus A (comparisons 3 and 4). Lines 200 mm long of stimulus A were compared to lines 200 mm long of stimulus B (comparison 5). Each of the five pairs of lines was presented six times, for a total of 30 trials. The positions of stimuli A and B were counterbalanced, so that each was presented on the left side in half of the trials, and on the right side in the other half. The pairs of lines were presented randomly.

Subjects were instructed to treat stimuli as if they were solid lines and asked to judge which of the two lines was longer. Subjects were given three seconds to respond, which was monitored by one of the experimenters using a hand held stopwatch. They were free to move their head or eyes. Between each trial subjects were shown a 7.8 × 7.8 mm circle, and asked to mark in its center. This distractor task was inserted to minimize contextual effects produced by previous stimuli across trials (Chatterjee et al., 2000; Marshall et al., 1998).

Results and Discussion

Normal subjects perceived lines made of shorter segments (stimulus B) as longer than lines made of longer segments (stimulus A) in 162 out of 240 trials (67.5%, range: 50.0%-83.3%). This proportion was significantly different ($p < 0.0001$) from chance, based on the Test for Significance of a Proportion

(Bruning and Kintz, 1977). The hypothesis that lines made of shorter segments would appear longer than lines made of longer segments was confirmed.

EXPERIMENT 2: LINE BISECTION

This experiment examined whether changing the internally represented lengths without changing the objective extents of lines would modulate bisection errors in neglect patients.

Materials and Methods

Subjects

Three patients with left neglect participated in the experiment (see Table I). Table II reports patients' performances on the Behavioral Inattention Test (BIT) (Wilson et al., 1987).

TABLE I
Demographic and Clinical Data of Neglect Patients.

Patient	Sex	Age	Education (years)	Lesion (CT scan)	Etiology
CG	F	58	12	TP	H
JF	M	58	12	FTP	I
OJ	M	58	16	TP	N

F = frontal, P = parietal, T = temporal; H = hemorrhage, I = ischemia, N = neoplasm.

TABLE II
Patients' Performances on the BIT

Patient	Line crossing	Letter cancellation	Star cancellation	Figure shape copy	Line bisection	Drawing
CG	17/36*	8/40*	12/54*	1/4*	3/9*	2/3*
JF	36/36	25/40*	40/54*	2/4*	9/9	1/3*
OJ	27/36*	15/40*	24/54*	1/4*	4/9*	3/3

An asterisk (*) indicates abnormal performances.

Stimuli and Procedure

The series of stimuli comprised two sets of horizontal lines 200 mm long and 1 mm wide. Lines were made of segments of different lengths. As in Experiment 1, the first set (stimulus A) consisted of lines made up of segments whose length varied from 20 to 38 mm. The second set (stimulus B) consisted of lines whose segments varied from 3 to 5 mm (see Figure 1). Ten different lines of each stimulus type were randomly presented twice, for a total of 40 lines. Lines were centered on 8.5×14 inches white sheets of paper oriented horizontally. Stimuli were centered on patients' sagittal midplane and presented on a table at a distance of approximately 50 cm.

Patients were required to treat stimuli as if they were solid lines. They were then asked to bisect the lines. There were no time limits and patients were free to move their head or eyes. Stimuli were presented in an alternating order. The deviation of the subjective midpoint from the true center of the lines was the dependent variable. Errors to the right of the line's midpoint were measured to the nearest millimeter.

Results

All three patients bisected lines made of shorter segments (stimuli B) significantly further to the right than lines made of longer segments (stimuli A). Bisection biases in conditions A and B were respectively + 4.85 mm (SD = 9.00) and + 14.05 mm (SD = 6.00) for patient CG, + 30.20 mm (SD = 6.90) and + 39.25 mm (SD = 7.27) for patient JF, and + 56.05 mm (SD = 13.79) and + 77.85 mm (SD = 4.57) for patient OJ. The mean errors of patients JF and OJ in condition A (+ 30.20 mm and + 56.05 mm respectively) ruled out the possibility that they could count the segments and bisect the middle one. Repeated measures t-tests showed that errors on stimuli A and B were significantly different for all patients: CG $t(19) = 5.11$, $p < 0.0001$, JF $t(19) = 4.12$, $p = 0.001$, OJ $t(19) = 6.20$, $p < 0.0001$.

Discussion

Patients with left-neglect make larger errors when bisecting longer lines than when bisecting shorter lines. We wished to learn if these errors could be influenced by the magnitude of the representations of lines, independent of their physical magnitude. Using principles underlying the Oppel-Kundt illusion, we constructed two kinds of lines of identical total length, but comprised of different segments. Normal subjects judged lines made of relatively short segments as longer than lines made of relatively long segments confirming our expectation that these lines of identical physical magnitude are represented differently. Our patients with neglect were also influenced by the visual illusion. They bisected lines, perceived by normal subjects as longer, further to the right than lines perceived as shorter. Our data confirm the notion that processes which generate illusions may be spared in neglect patients as has been reported previously with the Müller-Lyer illusion or its variant, the Judd illusion (Mattingley et al., 1995; Ro and Rafal, 1996). Ro and Rafal (1996) reported larger bisection errors in neglect patients with the lines perceived as longer (with fins projecting outward) than those perceived as shorter (with fins projecting inward). However, in the Müller-Lyer figures, the spatial extension of the entire stimulus increases when the direction of the fins changes from inward to outward. The line that is perceived as longer also has greater extension in space than the lines perceived as shorter. With these stimuli it is difficult to sort between external and internal contributions to the line length effect. By contrast, the lines used in our study encompassed the same spatial extent, despite being perceived as different.

Our finding cannot be explained by theories of neglect which emphasize the dynamics of spatial attention directed ‘externally’ to the contents of a visual scene. For example, Kinsbourne’s (1970, 1977, 1987) ‘orientational bias model’ suggests that neglect results from an imbalance between two opponent processors directing attention along the horizontal axis of space. This imbalance biases attention towards the ipsilesional side of the space. Therefore, patients act towards and more efficiently on stimuli in ipsilesional space. Several studies

suggest that these patients have an attentional gradient with 'hyperattention' to rightward stimuli and they probably scan stimuli from right-to-left. Làdavas (1990) investigated the performance of patients with visual extinction in attending to targets presented in three different locations (left, center or right). Patients' accuracy and reaction times to targets deteriorated from right to left. De Renzi et al. (1989) tested neglect patients in a search task, in which four letters were displayed to the right of a central fixation point. Patients responded most quickly to targets in the rightmost position and more slowly towards central targets. Similarly, Làdavas, Petronio and Umiltà (1990) showed that neglect patients were actually faster than control subjects in responding to targets in the rightmost location.

Anderson (1996) presented a mathematical model of 'salience' of points along the horizontal axis to account for line bisection performances by patients with neglect. The salience of these points was postulated to be a function of hemisphere attentional properties and it varied by spatial location. A line is bisected where the 'salience' of the left half of the line is equal to that of the right half. Following right brain damage the salience of the line shifts rightward. According to this model, longer lines have a greater rightward salience, and therefore longer lines are bisected further to the right. However, lines occupying identical physical space would have the same salience distribution and should be bisected similarly.

These external accounts support the idea that left-neglect patients orient further rightwards when stimuli extend further rightward. However, this influence of the location of stimuli on the rightward bias cannot account for our findings. We found that bisection errors were influenced even when stimuli encompassed the same physical space. In our patients the abnormal orientation bias was modulated by changes in the magnitude of internal representations, not the changes in the magnitude of physical stimuli. In these patients the visual illusion might be processed pre-attentively. Then the defective attentional mechanisms apply to the pre-attentively processed representations of the stimuli. These data, in line with previous findings (Bartolomeo et al., 1994; Bisiach et al., 1981; Bisiach and Luzzatti, 1978), underscore the important role of mental representations in the phenomenology of neglect.

Our results argue that the dynamics of internal representations can modulate the rightward orientation bias in neglect. The nature of these internal dynamics is not at all clear. Right hemisphere damage produces pathologic limitations in cognitive activation (Coslett et al., 1987). Chatterjee et al. (1992) proposed that neglect patients have a limited capacity to attend to or act upon stimuli. Our data suggest that some form of a limited capacity also applies to the maintenance of internal representations.

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