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Right up there: Hemispatial and hand asymmetries of altitudinal pseudoneglect

Ketchai Suavansri [a], Adam D. Falchook [b,c], John B. Williamson [b,c], Kenneth M. Heilman [b,c,*]

[a] Bumrungrad International Hospital, Bangkok, Thailand
[b] Department of Neurology and Center for Neuropsychological Studies, University of Florida, Gainesville, FL, United States
[c] Malcom Randall Veterans Affairs Medical Center, Gainesville, FL, United States

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ABSTRACT

Background: Pseudoneglect is a normal left sided spatial bias observed with attempted bisections of horizontal lines and a normal upward bias observed with attempted bisections of vertical lines. Horizontal pseudoneglect has been attributed to right hemispheric dominance for the allocation of attention. The goal of this study was to test the hypothesis that the upward bias in vertical line bisection may also relate to right hemispheric dominance for the allocation of attention and/or action-intention.
Methods: Twenty right handed healthy adults were asked to bisect vertical lines presented in the midsagittal plane (center space) and in sagittal planes to the left and right of the midsagittal plane (left and right hemispace) when using a pen held in either the right or left hand.
Results: Vertical line bisections were biased upward in all three sagittal planes and higher in left than right hemispace. However, bisections made with the left hand were lower than those made with the right hand.
Discussion: Whereas these results suggest a left hemispace-right hemispheric visuospatial attentional upward bias and a relative left hemispheric-right hand upward action-intentional bias, further studies are needed to document this intentional versus attentional bias and to understand the brain mechanisms that produce these biases.

1. Introduction

When healthy people attempt to bisect horizontal lines, they often deviate to the left, and this bias has been called "pseudoneglect" (Bowers & Heilman, 1980; McCourt, Freeman, Tahmahkera-Stevens, & Chaussee, 2001). This asymmetrical bias has been attributed to the right hemisphere's dominance in mediating spatial attention. Support for this postulate comes from the observation that when lines are presented in left body centered hemispace, primarily attended to by the right hemisphere, there is a greater leftward deviation then when the lines are presented in the center or right hemispace (Brodie, 2010). When performing a line bisection task, subjects need to view the entire line, requiring the use of a global attentional network. Previous studies have provided evidence that whereas focal attention is primarily mediated by the left hemisphere, it is the right hemisphere that mediates global attention (Robertson & Lamb, 1991). In addition, control of the left hand is primarily mediated by the right hemisphere and vice versa. When healthy right handed participants perform horizontal line bisections with the left hand, there is a greater leftward deviation as compared to horizontal line bisections performed with the right hand (Brodie, 2010).

When attempting to bisect vertical lines, healthy people often demonstrate an upward bias, called altitudinal pseudoneglect (Heber, Siebertz, Wolter, Kuhlen, & Fimm, 2010; Jewell & McCourt, 2000; Nicholls, Mattingley, Berberovic, Smith, & Bradshaw, 2004; Scarisbrick, Tweedy, & Kuslansky, 1987; Shelton, Bowers, & Heilman, 1990). Sheliga, Craighero, Riggio, and Rizzolatti (1997) also demonstrated that vertical saccadic reaction times are faster in the upward direction. These results can be interpreted in terms of an upward visual attentional bias and are compatible with the upward bias on vertical line bisection. Studies of patients with focal lesions have revealed that the ventral visual association areas appear to mediate attention to upper visual space, and the dorsal systems mediate attention to lower visual space (Rapcsak, Cimino, & Heilman, 1988; Shelton et al., 1990). It has been posited that the upward bias displayed by healthy subjects on a vertical line bisection test results from the ventral system's dominance in allocation of vertical attention (Drain & Reuter-Lorenz, 1996), but the reason for this dominance is not entirely known.

Since the reports of Balint (1909) and Lissauer (1890) in humans, as well as Mishkin and Ungerleider (1982) in monkeys, it has been recognized that the ventral stream of visual processing is important for object recognition (the "what" system) while the dorsal stream is important for spatial location in relation to the

* Corresponding author at: Department of Neurology, University of Florida, College of Medicine, McKnight Brain Institute (L3-100), 100 South Newell Drive, P.O. Box 100236, Gainesville, FL 32610-0236, United States. Fax: +1 352 273 5575.
E-mail address: Heilman@neurology.ufl.edu (K.M. Heilman).

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body (the "where" system). Performance on the line bisection task would appear to be more of a "where" than "what" process. In addition, functional MRI studies have demonstrated that performance of line bisection judgments (Fink, Marshall, Weiss, & Zilles, 2001) and covert orienting of visual spatial attention (Mao, Zhou, Zhou, & Han, 2007), both horizontal and vertical, activate parietal and parieto-occipital cortex, which are parts of the dorsal "where"' system. Thus, based on this "where" versus "what" dichotomy, it might have been expected that the dorsal stream would be more activated than the ventral stream, and healthy participants would have a downward bias in vertical line bisection. This is not the case.

Riestra, Womack, Crucian, and Heilman (2002) provided evidence that when bisecting lines, people attempt to divide the line into two segments and then compares the magnitude of these segments. Further support for this postulate comes from studies tracking eye movements. When neurologically intact participants view and attempt to bisect horizontal lines, the eyes fixate near the center of the line during the majority of time spent viewing the line (Barton, Behrmann, & Black, 1998; Ishiai, Furukawa, & Tsukagoshi, 1987). Thus, even prior to the actual bisection, neurologically intact participants appear to be dividing the line into two segments. Comparing two objects, in this case two line segments, may activate the ventral "what" system. In addition, object recognition (mediated by the ventral stream) is an allocentric task, and determining "where" in relation to the body is more of an egocentric task. Support for this dichotomy comes from studies of patients with strokes. Those with dorsal (parietal) lesions are more likely to have body centered neglect (Heilman and Valenstein, 1979; Hillis, 2006) and patients with temporal lesions are more likely to have allocentric neglect (Hillis, 2006). Foxe, McCourt, and Javitt (2003) demonstrated that the N1 component for the visual event related potential, a reflection of the time course for visual processing by the ventral stream, closely follows the time course of line bisection judgments. These findings suggest that an allocentric perspective of the line is necessary in order to estimate the midpoint, and the ventral visual network may mediate the allocentric perspective.

Whereas the postulate that the right hemisphere is dominant for mediating horizontal spatial attention and global attention may help explain the leftward pseudoneglect observed in the horizontal line bisection task, the influence of possible right hemispheric dominance in mediating upward vertical attention during vertical line bisection has not fully been tested. Studies of patients with hemispheric lesions as well as normal subjects have revealed that in addition to receiving visual input from the ipsilateral side of the retina in the left and right eye and thus the contralateral visual fields, each hemisphere appears to attend to contralateral body centered hemispace (Bowers, Heilman, & Van Den Abell, 1981; Heilman & Valenstein, 1979). In addition, visual input from the superior portion of the retina, which receives images from the inferior altitudinal field, primarily projects to the superior occipital cortex which is in close anatomical proximity to the parietal lobes. Visual input from the inferior portion of the retina, which receives input from the superior altitudinal field, primarily projects to the inferior occipital cortex which is in close anatomical proximity to the temporal lobes. Thus, while performing vertical line bisections, with the paper on which the line is printed presented in the coronal plane, such that the line is parallel to the participant and the center of the line is at eye level, when the subject fixates near the center of the line, the top half of the line will primarily project to the inferior retina and from there to the inferior occipital cortex and vice versa.

Since the role of the right versus left hemisphere in mediating this vertical bias has not been fully investigated, the purpose of this study is to examine, in healthy adults, the influence of the right and left hemispheres on these vertical spatial perceptual-attentional and action-intentional biases by comparing normal participants' performances on vertical line bisection tests in the left and right body centered hemispaces. Thus, to test the hypothesis that the right hemisphere has a greater propensity to allocate attention and action-intention to upper space than does the left hemisphere, and that this right hemispheric bias may help account for vertical upward pseudoneglect, we tested normal subjects' performance on vertical line bisections, using their right or left hands with these lines being presented in the coronal plane. Lines were placed at the coronal plane's intersection with the midsagittal plane, as well as in sagittal planes to the left and right of midline (left and right hemispace). Since the right hemisphere appears to be dominant for global attention and is more allocentrically oriented than the left hemisphere, and the right hemisphere mediates both attention and intention to act in the left body centered hemispace, we predicted that the upward vertical pseudoneglect would be greatest for vertical line bisections performed in the left hemispace and when the left hand was being used.

2. Methods

2.1. Participants

Twenty (11 men and 9 women) right handed subjects, as determined by Annett's (1970) handedness questionnaire (mean number of items answered as performed with the right hand = 11.9/12), who are without neurological, psychological or serious medical illness, participated in this study. Age ranged from 22 to 45 (mean = 32.3, SD = 8.6 years) and years of education years ranged from 12 to 23 (mean = 18, SD = 2.4 years). All subjects signed informed consents, and this study was approved by our university's institutional review board.

2.2. Apparatus

A white board measuring 4×3 ft (121.9 cm $\times$ 91.4 cm) was vertically attached to the wall in landscape orientation. Lines of 0.08 in. (2 mm) width and 9.45 in. (240 mm) length were printed on 8.5×11 in. (21.6 cm $\times$ 27.9 cm) white sheets of paper, centered in the middle of these papers. The white board had pin-point sized marks to guide placement of these sheets of paper, and these sheets were attached to the white board by small pieces of transparent adhesive tape. The visual vertical line bisections were performed in three spatial positions, at the midsagittal plane and in the sagittal planes that were 12 in. (30.5 cm) to the right and 12 in. (30.5 cm) to the left of the midsagittal plane. The vertical height, from the floor, of the white board with the attached lines was adjusted so that middle of these lines was aligned with the subjects' eyes.

2.3. Procedures

The subjects stood erect facing the board such that the front of their forehead was 14 in. (35.6 cm) from the board and their midsagittal plane bisected the board. The sheets of paper with a vertical line were attached to the board in one of the 3 spatial positions, one piece at a time. This setting makes the viewing angle of the left and right lines 41° from the subject's mid-sagittal plane. The order in which the vertical lines were presented in the three conditions was randomized. The subjects were allowed to freely move their eyes and head, but were not permitted to move their body or legs. The subjects were asked to bisect these vertical lines (i.e., "Place a mark in the middle of the line.") with a pen, using their right or left hand and each hand was used for half of the trials in each hemispace. After each of the attempted bisections, the paper was