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Perceptual-Attentional and Motor-Intentional Bias in Near and Far Space

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Abstract

Spatial bias demonstrated in tasks such as line-bisection may stem from perceptual-attentional (PA) “where” and motor-intentional (MI) “aiming” influences. We tested normal participants’ line bisection performance in the presence of an asymmetric visual distracter with a video apparatus designed to dissociate PA from MI bias. An experimenter stood as a distractor to the left or right of a video monitor positioned in either near or far space, where participants viewed lines and a laser point they directed under 1) natural and 2) mirror-reversed conditions. Each trial started with the pointer positioned at either the top left or top right corner of the screen, and alternated thereafter. Data analysis indicated that participants made primarily PA leftward errors in near space, but not in far space. Furthermore, PA, but not MI, bias increased bilaterally in the direction of distraction. In contrast, MI, but not PA, bias was shifted bilaterally in the direction of startside. Results support the conclusion that a primarily PA left sided bias in near space is consistent with right hemisphere spatial attentional dominance. A bottom-up visual distractor specifically affected PA “where” spatial bias while top-down motor cuing influenced MI “aiming” bias.

Keywords

line bisection; pseudoneglect; attention; perception; motor bias

Introduction

Patients with unilateral neglect demonstrate asymmetric spatial deficits behaviorally as a failure to report, respond to, or orient toward stimuli in contralesional space (Heilman, 1979). The heterogeneity of the neglect syndrome suggests that their deficits may stem from perceptual-attention (PA) or motor-intention (MI) sources or both (Barrett et al., 2006;

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Heilman, Watson, & Valenstein, 2003). PA deficits represent a lack of awareness of or attention to stimuli in the contralesional side of space that is not due to primary sensory deficits. MI deficits, alternatively, denote a failure to respond to or initiate action toward contralesional stimuli, even if they fall into conscious awareness, that cannot be attributed to primary motor deficits. Neglect patients tend to demonstrate spatial biases based predominantly on either PA or MI deficits when they are dissociated (Adair, Na, Schwartz, & Heilman, 1998; Bisiach, Geminiani, Berti, & Rusconi, 1990; Coslett, Bowers, Fitzpatrick, Haws, & Heilman, 1990; Na et al., 1998; Tegnér & Levander, 1991).

PA “where” and MI “aiming” biases have been dissociated experimentally by asking subjects to perform a visual-motor task in which the direction of action is dissociated from their viewed perception of their movement. For example, Bisiach and colleagues (1990) devised a pulley system with which subjects marked the center of a line by pulling a string. A marker on the line either moved in the same direction as the string they pulled, or in the opposite direction. When the marker moved in the opposite direction that the subjects moved the string, responses differed depending upon whether their deficit was in attending or in moving their hand leftward. Some investigators use a video apparatus designed along similar principles to horizontally dissociate perception and action (Adair, Na, Schwartz, & Heilman, 1998; Barrett, Crucian, Beversdorf, & Heilman, 2001; Na et al., 1998; Schwartz, Adair, Na, & Williamson, 1997). Nico (1996) utilized an epidiascope (overhead projector) to achieve mirror-reversed viewing conditions as a technique to detect directional hypokinesia. A verbal task has also been developed as a more flexible method for making this same type of dissociation (Chiba, Yamaguchi, & Eto, 2005).

The dissociation of PA and MI biases among neglect patients may reflect different underlying mechanisms for the disorder, as well as different neural systems involved in spatial perception (Heilman, 2004). If so, similar dissociations should be observable among neurally intact participants when they demonstrate a spatial bias. Normal subjects may exhibit such a bias when performing the line bisection test, erring to the left when attempting to mark the veridical center of the line (Jewell & McCourt, 2000). Because the performance of this task requires the coordination of visual perceptual and motor control skills, PA or MI biases may underlie the asymmetric performance. If the bias is related to a failure to attend to one side of the line, or an abnormal propensity to attend to the other side, then asymmetric perceptual-attentional (PA) awareness may be primarily responsible for errors. Alternatively, the bias might originate from asymmetries in premotor or motor-intentional (MI) functioning, with subjects demonstrating a preferential turning or aiming tendency.

Though PA “where” and MI “aiming” systems are intimately interrelated in spatial attention and action, leftward PA bias may primarily predominate in normal control groups (Schwartz et al., 1997; Barrett, Crosson, Crucian, & Heilman, 2002), suggesting right hemispheric attentional systems critically support task performance. The standard clinical administration of the line bisection task is in paper and pencil format, and therefore it must be carried out within arms’ reach in near peripersonal space. It is possible, therefore, that right hemispheric specialization may be especially robust in near space. To examine this possibility, Dellatolas, Vanluchene, and Coutin (1996) had normal subjects bisect lines in near space on paper and in far space on computer screens. They found that the slight leftward bias on paper was not present when subjects bisected lines in far space. Varnava, McCarthy, and Beaumont (2002) reported similar results when normal subjects bisected lines on a completely computerized task at four different distances ranging from near to far space. Subjects demonstrated leftward error in the nearest conditions that decreased as the lines were positioned further away, supporting the hypothesis that these differences are continuously related to viewing distance. The functional differences in performance between near and far space might be attributable to a greater contribution of attentional processing in far space (Previc, 1990). However, it is not known

whether in normal subjects an asymmetric bias may fractionate differently into PA and MI bias components depending upon whether tasks are performed in near versus far space.

In near and far space, other environmental conditions may influence spatial bias and cause distraction. Barrett, Schwartz, Crucian, Kim, and Heilman (2000) studied a patient with a left medial thalamic infarction who had spatial bias selective to far extrapersonal space. The subject used a laser pointer to bisect lines in near and far space. Although she performed comparably to control subjects in near space, she erred significantly rightward of controls (and the veridical center) when bisecting in far space. Interestingly, the patient also reported a tendency while driving to veer in the direction of objects appearing on the right side of the road, and the researchers included conditions in which an experimenter (distractor) stood physically to one side or the other of the line. The patient responded significantly rightward when the distractor stood on the right compared with trials in which the distractor was on the left, suggesting a distractor effect in far space only.

The asymmetric bias could have been either primarily PA or MI, as the motoric aspect of her responses was not spatially dissociated from visual-perceptual space. As a visual distractor would presumably engage bottom-up visual systems, it might primarily influence PA “where” bias. Alternatively, top-down motor programming may be expected to have a greater influence on MI “aiming” bias.

In the current study we experimentally examined normal control subjects’ spatial bias on the line bisection test by using a video camera, mixer, and monitor to dissociate subjects’ action space from the task viewing space. We expected to observe PA leftward bias in near space, but wished to identify whether reduced errors of a different character might occur when this task is performed in far space. Additionally, we hypothesized that the presence of an asymmetric distractor on the right or left might primarily influence PA response bias through a bottom-up influence, while asymmetric motor programming (i.e., instructing subjects to start on the left or the right side of the line) may primarily affect MI bias through a top-down influence.

Methods

Participants

Twenty-two right-handed volunteers (11 male) aged 21 to 35 (mean 24.8, SD 3.26) participated in the study. Subjects had no history of neurological or psychiatric conditions, and had normal or corrected to normal vision. They had a mean 16.6 (SD 1.60) years of education.

Apparatus

Subjects bisected lines by directing a Laserlyte laser pointer to a self-standing, non-glare, transparent acrylic workscreen, positioned on the floor (see Figure 1). The workscreen held a white sheet of paper with a black horizontal line, 22.4 cm long and 0.3 cm in width, centered on it, and was positioned 55cm in front of the subjects and 15 cm from the floor. A white sheet draped over the subject’s lap blocked a direct view of the workscreen, but a Sony (DCR-TRV730) Digital 8 camera positioned below the subject’s seat projected the workscreen and laser pointer position to a Sony television monitor (viewscreen). The viewscreen was located either 55 cm away from the subject in near space (40×30 cm viewscreen), or 175 cm away from the subject in far space (123 × 92.5 cm viewscreen). In both cases, the projected line subtended a visual angle of 38.1° and appeared at eye level. A videonics MXPro digital video mixer-TBC horizontally mirror-reversed the projected image in half of the trials (Indirect condition), such that the left side of the line appeared on the right side of the monitor and vice-versa. In left- and right-distractor trials, a second experimenter stood immediately to the left

or right side of the monitor as the subject bisected lines. For scoring subject performance, a second camera, identical to the one above, recorded the line and the laser pointer position from the back of the workscreen, to which a metric ruler was affixed.

Procedure

Subjects sat with their midsagittal planes aligned with the horizontal center of the workscreen and monitor, and held the laser pointer with both hands. They bisected lines in a total of 96 trials, split into four blocks (Near-Direct, Near-Indirect, Far-Direct, and Far-Indirect), performed in pseudorandom order. Each block was further divided into three Distractor condition sets (Left-, Right-, or No-Distractor), also pseudo-randomized. For each trial, subjects were instructed to begin by directing the pointer to either the left or the right upper corner of the workscreen. They then moved the pointer to bisect the line and verbally indicated when they were satisfied with the pointer location. In subsequent trials, they alternated starting in the right or left upper corner. In the Natural condition, subjects' movements corresponded to what they saw on the viewscreen, but in the Reversed conditions, moving the pointer to the right resulted in apparent leftward movement on the viewscreen, and moving the pointer to the left resulted in apparent rightward movement.

Analysis

Line bisection error from the veridical center was measured to the nearest millimeter by a rater later viewing subjects' videotaped performance. Leftward errors were coded as negative, and rightward errors as positive.

Perceptual-attentional (PA) "where" errors and motor-intentional (MI) "aiming" errors may reflect the contribution of feedback-dependent and feedback-independent spatial processing, respectively, in spatial errors. Ordinarily, feedback-dependent "where" and feedback-independent "aiming" error components contribute additively to the measured total magnitude of spatial errors. However, with visual feedback horizontally left-right reversed from the direction of movements, measured magnitude of spatial errors may be estimated by the difference between "where" and "aiming" error components. This may be reflected algebraically in the following equations:

$$\text{Natural} = \text{MI} + \text{PA}$$

$$\text{Reversed} = \text{MI} - \text{PA}$$

Subjects' errors were analyzed in a repeated-measures analysis of variance (ANOVA) with within-subjects factors Distance (near, far), Bias (MI, PA), Distraction (left, right, none), and Startside (left, right). Sex (male, female) was included as a between-subjects factor. The degrees of freedom for significant effects were adjusted with a Greenhouse-Geisser correction where appropriate. All reported effects are for two-tailed comparisons.

Results

Analyses were undertaken to determine if subjects would err further to the left in near space than in far space. Mean responses in near space ($M = -0.84$ mm, $SD = 1.52$) were indeed reliably to the left of those in far space ($M = -0.01$, $SD = 1.45$; significant main effect of Distance, $F(1,20) = 7.65$, $p = 0.012$). Furthermore, subjects erred significantly to the left of center when responding in near space alone ($t = 2.60$, $p = 0.017$, one-sample t -test), but not in far space ($t = 0.43$, *n.s.*).

Differences in error magnitude in near versus far space primarily could be either perceptual-attentional (PA) or motor-intentional (MI) in character. A distance x bias interaction, $F(1,20) = 5.28$, $p = 0.033$ revealed that the distance main effect was primarily carried by PA bias (see

Figure 2). To test the hypothesis that overall leftward PA “where” and MI “aiming” biases would be observed, *a priori*, one-sample t-tests were conducted for each bias in near and far space. Two-tailed comparisons revealed that only PA bias was significantly leftward of the veridical center in near space ($t = 2.12, p = 0.046$), but MI bias was not ($t = 0.27, n.s.$). Neither PA nor MI bias were significantly leftward of veridical center in far space (PA: $t = 0.12, n.s.$; MI bias: $t = 0.61, n.s.$).

We hypothesized that subject error would be influenced by the presence of an asymmetric bottom-up distractor, and that such an effect might be primarily attributable to PA bias. A distraction $\times$ bias interaction, $F(2,40) = 11.16, p = 0.001$, supported this hypothesis, indicating that PA but not MI bias, increased bilaterally in the direction of the distractor (see Figure 3). That is, when the distractor was located on the left, responses were significantly leftward of those from the no-distractor condition ($t = -3.54, p = 0.002$). Conversely, when the distractor was on the right, responses were significantly rightward of those in the no-distraction condition ($t = 3.04, p = 0.006$). None of the distraction comparisons for MI Bias were significant.

We also hypothesized that the instruction to start on one side of the line or the other (startside) would influence responding in a top-down manner, affecting MI bias. A startside $\times$ bias interaction, $F(1,20) = 7.82, p = 0.011$, confirmed that indeed MI, and not PA, bias increased in the direction of the starting side. That is, MI bias was further to the left in left startside trials ($M = -0.40$ mm, $SD = 1.57$) and further to right in right startside trials ($M = 0.13, SD = 1.00$; $t = 2.34, p = 0.029$). None of the startside comparisons for PA bias were significant.

Discussion

In this study, normal control subjects bisected lines in near and far space. By dissociating perceptual and action space, we sought to fractionate the effects of perceptual-attentional (PA) and motor-intentional (MI) bias.

Previous investigators found that normal subjects made greater leftward errors when they bisected lines in near versus far space (Dellatolas et al., 1996; Varnava et al., 2002). Our results are consistent with these prior reports. Additionally, the near leftward errors made by our subjects were primarily accounted for by feedback-dependent, PA “where” bias. Varnava et al. found both slight leftward and rightward bias for line bisections performed in their furthest conditions (120 cm from subjects) for their longest line lengths (7.59 degrees). The direction of the bias for these conditions depended on which side of the screen the cursor started. However, PA and MI bias were not dissociated in that study, so it is unclear whether their results were related to perceptual-attentional or motor-intentional processing. In the current study, the distance for far space was further away than any of the conditions used by Varnava et al., (175 cm) and the line length used was longer than the longest lengths used in that study. Additional experiments will be needed to determine whether our failure to replicate rightward bias in far space may be partly related to the line length or distance we used.

We investigated the effect of an asymmetric visual distractor, an experimenter standing to one side of the line to be bisected, which we believe may constitute a bottom-up type influence on perceptual-attention. As hypothesized, there was no effect of this distractor on MI “aiming” bias, but PA “where” bias was altered in the direction of the distractor, with leftward error increasing in the presence of a left distractor, and decreasing in the presence of a right distractor. Previous studies reported that attentional cuing shifted line bisection error in the direction of the cue (Milner, Brechmann, & Pagliarini, 1992; Nichelli, Rinaldi, & Cubelli, 1989; Reuter-Lorenz, Kinsbourne, & Moscovitch, 1990; McCourt, Garlinghouse & Reuter-Lorenz, 2005), or when cues were presented on both sides, toward the cued which was engaged first (Fischer,

1994). However, in this study, a static attentional distractor also influenced line bisection performance.

In prior cuing studies, the cues may have altered the perceived length of the line, augmenting it (Milner et al., 1992; Nichelli et al., 1989) or shortening it (Chieffi & Ricci, 2002) at one end. In the present study, distractors were spatially removed and distinct from the line. Thus, our stimuli not only activated bottom-up attentional systems more strongly than cues used in prior studies, but may have been less likely to act upon central representations of the line itself than those used in previous research. Because they were experimenters, the saliency of the current of distractors may have been an important aspect of the influenced spatial bias. For example, Tamietto et al. (2005) found that emotional face cues reduced line bisection errors relatively more than neutral face cues, suggesting that the increased saliency of the affective cues biased attention and not just perceived line length. Similarly, an actual human may have a similar direct effect on attention and spatial bias. Finally, detection of distractors in our study also was not confounded by the over-learned scanning eye movements involved in reading, which has affected bias in other studies of cuing in the line bisection task (Fischer, 1994).

We hypothesized that a top-down motor instruction to begin trials pointing to one side of the workscreen, would affect MI “aiming” bias. Indeed, leftward MI bias increased for trials starting on the left as compared with trials starting on the right. This is consistent with prior studies investigating the effects of directional scanning on line bisection, in which responses shifted toward the scanning startside (Bradshaw, Nathan, Nettleton, Wilson, & Pierson, 1987; Chokron, Bartolomeo, Perenin, Helft, & Imbert, 1998). An important consideration for the current study, however, is that the direction of scanning eye movements was dissociated from the direction of laser pointer movement in half of the trials. In mirror-reversed trials, when the subjects started on the left side of the screen, the pointer appeared on the right side of the video monitor. Thus, scanning eye movements may have been reversed in direction. Because MI “aiming” bias was shifted in the direction of startside, independent of whether eye movements were cued in the same or the opposite direction, this supports MI bias as being tied to early, ballistic motor-preparatory processing, to limb as opposed to eye movement, or both.

The current findings support and validate the PA/MI “where” versus “aiming” construct distinction by demonstrating that they indeed may be separable bias components. In this experiment, the effect of the visual distractor was primarily PA, while the effect of startside was primarily MI. Thus, the bias components did not interact with each other, and were independently affected by the two manipulations of distractor and startside. This double dissociation provides strong support to PA and MI bias as indicative of unique, discrete processes.

The current study is limited to the extent that the line bisection task is generalizable to other tasks and behaviors. It will be important to determine whether the same spatial bias dissociations are attainable in other tests of spatial processing, including other common bedside tests such as cancellation tasks. The particular features of the current paradigm also warrant further investigation. For example, the type of object used for a distractor may have an important effect on the magnitude of bias exhibited. In the current study, a second experimenter stood as a distractor, but it is unclear whether inanimate objects with differing degrees of relevance to the participant may have differential effects on spatial bias.

It is important to understand whether PA and MI spatial bias may contribute differently to acquired spatial neglect, as this implies that further analysis of subgroups may be important in treatments with purported small group effect sizes (Marshall, Halligan, & Robertson, 1993; cf. Barrett et al., 2006), and that “recovered” neglect may differ categorically depending upon whether both PA and MI bias decrease. Distinct neural systems may mediate visuomotor

processing in near versus far space (Weiss et al, 2000), which may be selectively impaired by brain injury. Dynamic or multitasking conditions, which are frequently encountered in daily life and understudied in neglect, may differentially affect one type of bias. This may affect patients acutely or in chronic stages, and may even affect patients with other attentional disorders. It is known that distraction adversely affects attentionally demanding activities such as driving in young healthy subjects (Chen, Baker, Braver & Li, 2000). Further studies of young, aged, and brain-injured subjects, including both experimental and functional tasks, are needed in order to clarify whether the current constructs provide a meaningful way of analyzing life-relevant spatial errors.

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Figure 1.

Experimental apparatus for bisecting lines in a) near and b) far space. Subjects directed a laser pointer to the front of a work screen which was projected on one of two monitors, and data were recorded from behind the workscreen on a separate camera.

Figure 2.

Bias x Distance interaction. PA bias was significantly leftward in near space but not in far space (* $p < .05$), but MI bias did not differ from zero at either distance.

Figure 3. Bias x Distraction interaction. PA bias shifted leftward in the presence of a left distracter and right in the presence of a right distracter (**p < .01).