

BRIEF COMMUNICATION

The influence of viewing eye on pseudoneglect magnitude

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Abstract

Various factors influence the degree of leftward error (pseudoneglect) that typifies the performance of normal individuals in line bisection tasks. This experiment reveals that the eye through which stimuli are viewed also exerts a modulating influence on spatial attention, as indexed by significant alterations in the magnitude of pseudoneglect. Using a forced-choice tachistoscopic line bisection protocol, 24 participants (12 male; 12 female) bisected horizontally oriented lines ($22.6^\circ \text{ w} \times 0.39^\circ \text{ h}$) presented to central vision in 3 conditions: left uniocular viewing (L), right uniocular viewing (R), and binocular viewing (B). Perceived line midpoint, a measure of bisection accuracy, deviated significantly leftward of veridical ($p < .05$) in all viewing conditions, confirming a tonic asymmetry of visuospatial attention in normal young observers. In addition, a significant influence of viewing condition was found ($p < .05$) where pseudoneglect was greatest in the L condition, followed by the B and R conditions, respectively. Analysis of the slopes of the psychometric functions revealed significantly greater bisection precision in the binocular versus uniocular viewing conditions ($p < .05$). The results are interpreted to suggest that phasic effects on spatial attention can be produced by uniocular viewing via asymmetric retinotectal projections. The results are consistent with activation–orientation theories of attentional asymmetry. (*JINS*, 2001, 7, 391–395.)

Keywords: Line bisection, Pseudoneglect, Spatial attention, Uniocular, Binocular

INTRODUCTION

Research into the etiology of and rehabilitative measures for visuospatial hemineglect has explored a variety of experimental procedures, including cutaneous electrical (Vallar et al., 1995) or mechanical (Karnath et al., 1993) stimulation, caloric vestibular stimulation (Cappa et al., 1987; Rubens, 1985; Storrie-Baker et al., 1997), optokinetic stimulation (Butter & Kirsch, 1995; Butter et al., 1990;), and unilateral eye patching (Butter & Kirsch, 1992; Soroker et al., 1994; Walker et al., 1996). The efficacy of these manipulations has been interpreted to imply that contralesional stimulation (or alternatively, ipsilesional deprivation) evokes asymmetric activation of the cerebral hemispheres in a manner that favors the afflicted (usually right) hemisphere (Storrie-Baker et al., 1997), thus temporarily equilibrating the tonic imbalance in hemispheric activation (and orienting) that ensues from the lesion (Kinsbourne, 1970, 1993).

Based on a report by Hubel et al. (1975), Posner & Rafal (1987) provide the following theoretical rationale for ipsilesional eye patching:

Unlike the geniculostriate cortical visual system, the collicular midbrain system is mainly crossed. The predominant visual input to the left superior colliculus comes from the right eye. Therefore, by patching the right eye, it might be possible to functionally deafferent the left superior colliculus and thereby, hopefully, to decrease visual neglect in the left visual field in patients with right parietal lesions. (p. 199)

The superior colliculi are retinotopically organized and, in primates, a representation of the contralateral visual hemifield is mapped onto each colliculus. By virtue of the denser nasal projection, however, the left hemifield is preferentially represented with left eye viewing, whereas the right hemifield is privileged under conditions of right eye viewing. The influence of these asymmetric subcortical projections on visual attention was recently demonstrated in human subjects by Zackon et al. (1997), who used the attention-induced apparent line motion technique of Hirasaka et al. (1993), in conjunction with uniocular viewing.

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Using a line bisection task, Butter and Kirsch (1992) measured the effects of unilateral eye patching in neglect patients and in a normal control group. They found that while the bisection performance of many neglect patients changed in a manner consistent with the hypothesis of Posner and Rafal (1987), that is, right eye patching led to decreased rightward bisection errors, there was no significant change in the performance of control subjects as a function of unocular viewing condition.

Jewell and McCourt (2000) performed a meta-analysis of the line bisection literature incorporating 73 studies and over 2000 participants. They report that in forced-choice bisection studies pseudoneglect (i.e., the leftward error of normal participants on line bisection tasks; Bowers & Heilman, 1980) possessed an effect size of -1.3 , whereas in studies utilizing the traditional manual method of adjustment technique, pseudoneglect possessed an effect size of only -0.4 . This raises the possibility that the nonsignificant unocular viewing effects reported by Butter and Kirsch (1992) for normal participants might have accrued, not from a lack of effect, but rather from insufficient experimental power. The following study is a replication of the normal control condition of Butter and Kirsch (1992), using an assay of attentional asymmetry possessing a threefold increase in sensitivity, to readdress the question of whether systematic alterations in the magnitude of pseudoneglect are induced by unocular viewing.

METHODS

Research Participants

A total of 24 right-handed participants (12 male, M age = 20 years; 12 female, M age = 19.1 years) participated in the experiment. Laterality was assessed using a standard instrument (Oldfield, 1971) on which a composite score of -100 denotes exclusive left-handedness, and $+100$ denotes exclusive right-handedness. The mean laterality score for male participants was $+70.4$ ($SE = 4.6$); that for female participants was $+79.6$ ($SE = 7.2$). There was no significant difference in mean age or laterality across male and female participants [$t(22) = 1.96, p > .05$; and $t(22) = -1.06, p > .05$, respectively].

Instrumentation and Calibration

Responses were sensed and collected, and stimuli were presented using IBM-compatible microcomputers with 640×480 pixel VGA graphics adapters. Monitor frame refresh rate was 60 Hz. The generation and sequencing of stimuli and the collection of subject responses were accomplished using the ERTS (Experimental Run Time System) software package (Beringer, 1995).

Stimuli

Stimuli were horizontally oriented lines of 100% Michelson contrast presented on a gray background (mean lumi-

nance = 30 cd/m^2). At a viewing distance of 45 cm lines subtended 22.6° in width by 0.39° in height. See McCourt and Jewell (1999) for images of the actual line stimuli.

All lines were pretransected prior to presentation. Transectors were located at 25 positions ranging from $\pm 0.88^\circ$ visual angle relative to veridical line center. This range of transector locations was sufficient to produce near-asymptotic "left" or "right" judgments in most participants.

Procedure

Participants were seated upright in straight-backed chairs. Their midsagittal planes were aligned with the display monitor, and viewing distance and head orientation were controlled using a chinrest apparatus. On each trial participants made single-interval forced-choice decisions regarding transector location relative to veridical center by depressing either the left or right mouse button as appropriate. Button orientation corresponded to the axis of perceptual discrimination (i.e., the "left" response button was to the left of the "right" response button). Participants responded using both right and left hands in separate blocks of trials. Order of hand use was counterbalanced within and across participants.

Tachistoscopic presentation was used to limit scanning eye movements. Pretransected lines were presented for 150 ms; intertrial intervals were variable since subsequent trials began 750 ms following previous responses.

Each participant viewed stimuli in all three experimental conditions: two unocular conditions: left eye viewing (L), right eye viewing (R), and a binocular condition (B). In unocular conditions, the occluded eye was covered with a comfortable lightproof eye patch. In all conditions, stimuli were viewed through natural pupils.

Subjects made eight "left-right" judgments in conjunction with each line transector location, such that determinations of subjective line midpoint (see below) were made based on 200 (25 transector locations \times 8 judgments per location) forced-choice bisection trials. Line transector position was randomly interleaved within blocks of trials. Hands used to respond and viewing condition was blocked. Order of presentation of blocked variables (hand and viewing condition) was counterbalanced across participants using a Latin-square design.

Design and Analysis

The dependent measure was the number (or percent) of trials on which participants indicated that the transector was located to the "left" of perceived line midpoint. The method of constant stimuli was used to derive psychometric functions and nonlinear regression was performed to fit a cumulative Gaussian distribution to these psychometric functions by method of least squares. The cumulative Gaussian function is described by Equation 1:

$$f(x, \alpha, \beta, \sigma) = \alpha(50 + 50(\text{erf}((x - \beta)/2^{0.5}\sigma))), \quad (1)$$

in which x is transector location, α is an overall gain parameter, β is the x -axis location corresponding to the mean of the underlying Gaussian density function (i.e., the transector location at which left-right responses occur with equal frequency), and σ is its standard deviation. The error function (erf) is an approximation to the cumulative Gaussian distribution, for which there is no closed-form analytical expression.

Based on these least-squares fits, the transector location corresponding to a 50% "left" response rate (β), and standard deviation (σ) were extracted. The transector location for which "left" and "right" responses occur with equal frequency is known as the "point of subjective equality" (p.s.e.) and is an objective measure of perceived line midpoint. While p.s.e. values index bisection accuracy, the standard deviation of the cumulative Gaussian function (σ), is a measure of bisection precision.

RESULTS

Bisection Accuracy

Figure 1 plots mean perceived line midpoint (p.s.e., ± 1 SEM) as a function of viewing condition. The results of a 2×3 (Sex \times Viewing Condition) mixed ANOVA revealed no significant main effect of subject sex [$F(1,22) = 0.08$, $p > .05$] and no significant Sex \times Viewing Condition Interaction [$F(2,44) = 1.86$, $p > .05$]. There was, however, a significant main effect of viewing condition [$F(2,44) = 4.25$, $p = .02$]. Collapsed across sex, an *a priori* contrast analysis revealed a significant linear trend between p.s.e. and viewing condition [$F(1,23) = 5.96$, $p = .02$], such that leftward bisection error was greatest in the left eye viewing condition (L), intermediate in the binocular condition (B), and least in the right eye condition (R). Finally, single-sample t tests confirmed that in all three viewing conditions

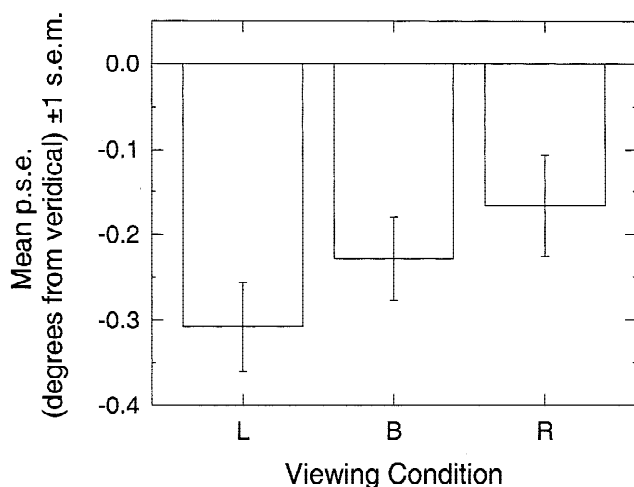


Fig. 1. Bisection accuracy. Mean perceived line midpoint (p.s.e.), in degrees visual angle relative to veridical line midpoint, is plotted as a function of viewing condition.

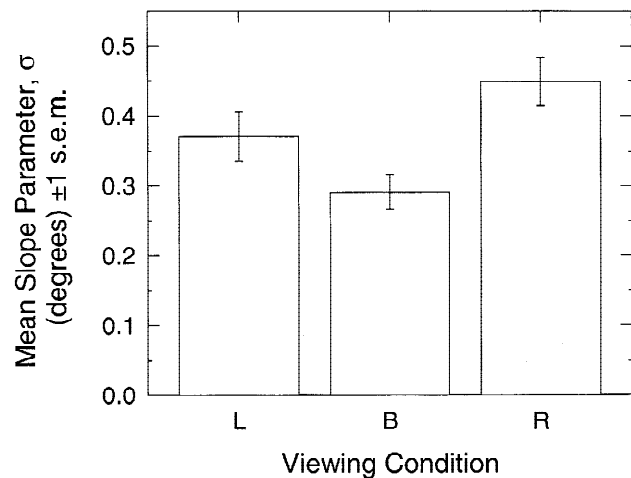


Fig. 2. Bisection precision. Mean slope parameter (σ), in degrees visual angle, is plotted as a function of viewing condition.

perceived line midpoint deviated significantly to the left of veridical: [L (-0.308°): $t(23) = -5.89$, $p < .001$; B (-0.228°): $t(23) = -4.71$, $p < .001$; R (-0.166°): $t(23) = -2.79$, $p = .011$].

Bisection Precision

Figure 2 plots the mean slope parameter, σ (± 1 SEM), as a function of viewing condition. The values of σ were obtained by fitting cumulative normal distributions (Equation 1) to the psychometric data. The value of σ is inversely related to the slope of the psychometric function as it passes through the point of subjective equality (p.s.e.). The steeper the slope of the psychometric function, the smaller the range of transector locations over which "left" judgments transit to "right" judgments (or *vice versa*). Thus, small values of σ imply that the observer is highly sensitive (i.e., can respond differentially) to changes in transector location around the point of subjective equality (p.s.e.), and that perceived line midpoint is judged with a high degree of precision. Note that high bisection precision does not necessarily imply high bisection accuracy; these two measures of bisection performance can vary independently.

The results of a 2×3 (Sex \times Viewing Condition) mixed ANOVA revealed no significant main effect of sex [$F(1,22) = 0.38$, $p > .05$], and no significant Sex \times Viewing Condition interaction [$F(2,44) = 1.05$, $p > .05$]. As was the case for the accuracy measure (p.s.e.), there was a significant main effect of viewing condition [$F(2,44) = 8.83$, $p = .001$]. Collapsed across sex, the mean slope of the psychometric functions of observers is significantly steeper (σ smaller) in the binocular condition than in either unocular condition [R vs. B: $t(23) = 4.21$, $p < .001$; L vs. B: $t(23) = 2.14$, $p < .05$]. A paired-samples t test reveals that the difference in the mean value of σ in the R and L viewing conditions is also marginally significant [$t(23) = 2.05$, $p = .051$].

DISCUSSION

Consistent with meta-analytic trends of normal participants in line bisection tasks (Jewell & McCourt, 2000), we found a significant pattern of leftward error (pseudoneglect) among our college age participants in all three viewing conditions.¹ One common explanation for pseudoneglect is that it reflects a structural specialization of the right cerebral hemisphere for the allocation and control of spatial attention (Mesulam, 2000). That the right hemisphere plays a privileged role in spatial attention is underscored by the fact that hemispatial neglect syndrome is most frequently associated with right hemisphere damage, and only rarely accompanies damage to the left hemisphere (Mesulam, 2000; Vallar & Perani, 1987). A related, and not mutually exclusive, explanation is that the right hemisphere is preferentially activated during the execution of tasks (e.g., "spatial" tasks, such as line bisection) for which it is structurally specialized (Hellige, 1993). We have presented evidence that pseudoneglect and neglect are complimentary phenomena (Mccourt & Jewell, 1999). Like neglect, pseudoneglect arises due to an asymmetric allocation of attention; except that in normal observers it is the left half of space (or objects) that enjoys the surplus, thus inducing a mild right-side "neglect."

We also found a significant modulating (phasic) effect of viewing condition superimposed on the tonic leftward error. The magnitude of left error was greatest for stimuli viewed through the left eye, and was least for stimuli viewed through the right eye. This effect of viewing condition is compatible with the opponent-process hypothesis articulated by Posner and Rafal (1987), *viz.*, that the functional deafferentation of the left colliculus produced by right eye patching releases the right colliculus from inhibition, thus leading to increased right hemispheric activation and a heightened asymmetry of attention (Kinsbourne, 1970, 1993). This result is equally compatible with an activation-arousal hypothesis (Heilman & Valenstein, 1972; Mesulam, 1982), in which left eye viewing directly results in a relatively greater activation of the contralateral (right) hemisphere, via collicular-cortical projections (Mesulam, 2000).

Our findings are in agreement with the majority of studies from the experimental psychology and visual science literature as well. For example, Brown (1953) reported that bisection errors made by normal participants using the left eye deviated significantly further leftward than those made using the right eye.² Similarly, Mefferd et al. (1969) found a difference between left and right eye bisection performance comparable in magnitude to that obtained in the present study, with left eye bisections being displaced fur-

ther leftward than right eye bisections. More recently, Graefe and Haase (1997) also report that bisections made while viewing lines or gaps with the left eye deviated further leftward than did bisections made using the right eye.

Our analysis of bisection precision, as indexed by the slopes of the psychometric functions, is novel and reveals several interesting points. First, bisection precision in the binocular viewing condition is significantly greater than in either unocular condition. This improvement in positional discrimination under binocular *versus* unocular viewing implies a binocular integration of position information. It is also noteworthy that bisection accuracy (p.s.e.) and precision (σ) measures vary with viewing conditions in dissimilar patterns, implying that the effects of viewing condition on bisection accuracy can not be ascribed in any simple manner to changes in bisection precision.

In summary, using tachistoscopic forced-choice line bisection, a psychophysical technique that is a more sensitive indicator of the perceptual components of attentional asymmetry than is the traditional method-of-adjustment line bisection procedures (Jewell & McCourt, 2000), we confirm the existence of tonic leftward error (pseudoneglect) in neurologically normal participants. In addition, we confirm that viewing eye has a significant modulating influence on the size of the effect, with left eye viewing producing the greatest leftward error.

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¹Age significantly modulates the pseudoneglect effect (Jewell & McCourt, 2000), such that normal older observers demonstrate weak leftward (or even modest rightward) error.

²Brown (1953) presents a concise review of mid-to-late 19th and early 20th century literature pertaining to the effect of viewing eye on line bisection. A majority of early studies report greater leftward deviations for left *versus* right unocular viewing.

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