

Does spatial cueing affect line bisection in chronic hemianopia?

C. Kuhn^a, A. Rosenthal^a, P. Bublak^b, K.H. Grotemeyer^c, S. Reinhart^a, G. Kerkhoff^{a,*}

^a Clinical Neuropsychology Unit at Saarland University, Germany

^b Neurological Clinic, University of Jena, Neuropsychology Unit, Germany

^c Neurological Clinic, Klinikum Saarbrücken, Germany

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ABSTRACT

Patients with homonymous hemianopia often show a contralesional shift towards their blind field when bisecting horizontal lines (“hemianopic line bisection error”, HLBE). The reasons for this spatial bias are not well understood and debated. Cueing of spatial attention modulates line bisection significantly in patients with visuospatial neglect. Moreover, recent evidence showed that attention training significantly improves deficits of visual search in hemianopia. Here, we tested in 20 patients with chronic homonymous hemianopia (10 left-sided, 10 right-sided) without visual neglect, 10 healthy control subjects, 10 neurological control patients, and 3 patients with left visuospatial neglect and leftsided hemianopia whether spatial cueing influences the HLBE. Subjects indicated verbally the midpoint of horizontal lines in a computerized line bisection task under four experimental cue positions (cue far left, mid-left, mid-right or far-right within the horizontal line). All 20 hemianopic patients showed the typical HLBE towards their blind field, while the two control samples showed only a small but significant leftward shift (pseudoneglect). None of the 4 cueing manipulations had a significant effect on the HLBE in the hemianopic patients. Moreover, no differential effects of cueing on line bisection results were obtained when analyzed in lesion subgroups of hemianopic patients with circumscribed occipital lesions ($N=8$) as contrasted with patients having more extended (occipito-temporal or temporal) lesions ($N=12$). This null-effect contrasts with marked cueing effects observed in 3 neglect patients with left hemianopia in the same tasks, showing the principal efficacy of our cueing manipulation. These results argue against attentional explanations of the HLBE.

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1. Introduction: hemianopic line bisection error (HLBE)

Unilateral lesions of the posterior visual pathways in the human brain often cause contralateral homonymous visual field defects (Miller, Newman, Biouesse, & Kerrison, 2008). Typically, patients with such scotomas show a variety of associated disorders (for review see (Lane, Smith, & Schenk, 2008), including hemianopic alexia (Kerkhoff, Münßinger, Eberle-Strauss, & Stögerer, 1992; Pflugshaupt et al., 2009; Schuett, 2009; Spitzyna et al., 2007), inefficient visual search in the scotoma (Keller and Lefin-Rank, 2010; Lane, Smith, Ellison, & Schenk, 2010; Machner et al., 2009)) and a peculiar spatial bias towards their blind field when bisecting long horizontal lines or indicating their subjective visual straight ahead. Although completely forgotten for several decades (Kerkhoff & Bucher, 2008) this spatial bias is well known as the hemianopic

line bisection error (further termed HLBE) since Axenfeld’s seminal description in 1894 (Axenfeld, 1894). Recent investigations have largely replicated and extended these early findings (Doricchi et al., 2005; Kerkhoff & Schenk, 2011; Schuett, Dauner, & Zihl, in press; Zihl, Sämann, Schenk, Schuett, & Dauner, 2009). Besides horizontal deviations in line bisection (Barton & Black, 1998; Doricchi et al., 2005; Hausmann, Waldie, Allison, & Corballis, 2003; Zihl et al., 2009) or in the visual subjective straight ahead orientation (Ferber & Karnath, 1999), vertical shifts in altitudinal hemianopia (Kerkhoff, 1993), or oblique shifts of the subjective visual straight ahead in homonymous quadrantanopia (Kuhn, Heywood, & Kerkhoff, 2010) were found. This *contralesional* spatial error contrasts with the well-known *ipsilesional* spatial error in the same tasks in patients with visuospatial neglect (Halligan, Manning, & Marshall, 1990; Schindler & Kerkhoff, 2004).

Despite this convergence of results demonstrating the existence of a contralesional spatial-perceptual bias in different types of hemianopia (HA) or other types of visual field defects, the precise reason(s) for its occurrence are less clear and currently debated (Kerkhoff & Schenk, 2011). Early researchers of the HLBE advanced several theoretical explanations of this error (Kerkhoff & Bucher, 2008). One prominent account surmised that the HLBE towards the

Abbreviations: HA, hemianopia; HLBE, hemianopic line bisection error.

* Corresponding author at: Saarland University, Clinical Neuropsychology Unit & University Ambulance, Building A.1.3., D-66123 Saarbrücken, Germany.
Tel.: +49 681 302 57380; fax: +49 681 302 57382.

E-mail address: kerkhoff@mx.uni-saarland.de (G. Kerkhoff).

blind field reflects a kind of adaptive, oculomotor strategy which helps the patient to orient his eyes and attention further towards the blind field, which in turn might improve visual orientation and reduce the typical visual complications such as bumping into obstacles or disregarding persons on the blind side (Gassel & Williams, 1963). A recent study (Machner et al., 2009) reported no contralesional HLBE in acute HA and speculated that the HLBE in chronic HA thus may result from slow, strategic, attentional adaptation to the scotoma. However, another recent study found no difference in the amount of the HLBE in acute versus chronic HA, and found in nearly all patients the typical contralesional error which was causally related to lesions of the lingual gyrus and cuneus (Baier et al., 2010). Their data do not support an interpretation of the HLBE as an attentional and oculomotor adaptation to the scotoma, but rather interpret it as a direct consequence of the extrastriate cortical lesion.

If the HLBE reflects or facilitates attentive orienting towards the blind field, experimental manipulations which direct spatial attention to or away from the blind side should modulate the HLBE in HA, just as they have been shown to modulate the ipsilesional line bisection error in patients with visuospatial neglect (Butter, Kirsch, & Reeves, 1990; Lin, Cermak, Kinsbourne, & Trombly, 1996; Riddoch & Humphreys, 1983). To our knowledge, no study so far has investigated the role of spatial cueing in the HLBE. We therefore investigated in the present study in matched samples of rather chronic patients with left versus right-sided HA – all without unilateral visual neglect – control patients with acquired brain damage but without HA or neglect, and healthy control subjects whether spatial cueing modulates the HLBE. In addition we tested the principal efficacy of our spatial cueing paradigm in 3 patients with leftsided neglect and leftsided hemianopia.

2. Methods

2.1. Patients and control subjects

20 patients with perimetrically established unilateral, homonymous HA following unilateral posterior cerebral lesions (10 left-sided, 10 right-sided; see Table 1) and 10 patients with unilateral or diffuse-disseminated brain lesions, but with perimetrically intact visual fields were tested (further termed brain damaged control patients; Table 1). Stroke was the most frequent aetiology in the HA sample ($n = 17$, 85%), followed by tumour operated ($n = 2$, 10%) and closed head trauma ($n = 1$, 5%). In addition, 10 healthy, dominantly right-handed (handedness-quotient of +100 in all cases) control subjects (8 males, 2 females, mean age 50.5 years; range 22–70) were recruited. None of the healthy control subjects had evidence of ophthalmological, neurological or psychiatric disease. All had perimetrically normal visual fields, and a mean visual acuity of 0.98 (mean, range 0.7–1.2) for the near visual distance (0.4 m) in a standardized letter acuity chart.

In addition, three patients with leftsided spatial neglect and leftsided hemianopia after a right middle cerebral artery stroke (9, 11 and 12 months after stroke, respectively) were tested. All three patients were righthanded (+100 laterality quotient) and showed symptoms of leftsided visual neglect in several of the 5 neglect screening tests. In manual horizontal line bisection, 2 patients showed a rightward shift: Patient 1: +19 mm, Patient 2: +10 mm. Patient 3 showed a leftward shift: –6 mm away from the true centre. In number cancellation all 3 patients omitted targets on the left side and to a smaller degree also on the right side (patient 1: 8 left vs. 3 right, patient 2: 3 vs. 1; patient 3: 2 vs. 1). Patient 1 showed leftward omissions when drawing a clock face from memory, patient 2 drew a normal clock face from memory, patient 3 showed distortions of the left side of the clock face and incorrect placement of the numerals on the left side of the clock face. Patient 1 and 2 showed signs of leftsided neglect in figure copying, patient 3 not. Patient 1 showed 11 omissions in the indented reading test, patient 3 showed 2 leftsided omissions, while patient 2 scored normally in the reading task. Visual perimetry revealed leftsided HA in all three cases (field sparing on the horizontal meridian: 4°, 6° and 2°, respectively). Visual search field was 16° in patient 1, and 33° in patient 2 in the left (blind) hemifield (search field could not be determined in patient 3 due to use of an automatic perimeter not allowing the manual measurement of the search field). In sum, all three patients had chronic leftsided HA plus leftsided visuospatial neglect.

All HA patients received visual exploration training (Kerkhoff, Münßinger, & Meier, 1994) as well as hemianopic reading training (if they showed hemianopic alexia, Kerkhoff & Marquardt, 2009) over a time period of 4–6 weeks. All investigations of the current study were carried out before these treatments started, so that the treatments could have no differential effect on the current results. Brain

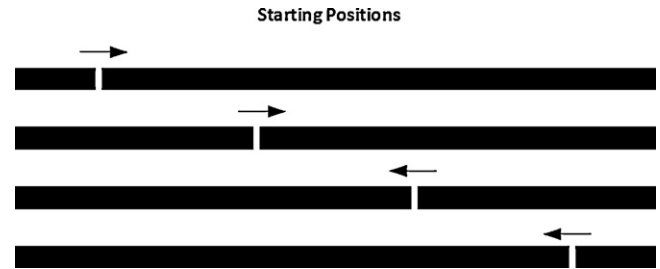


Fig. 1. Schematic illustration of the 4 line bisection tasks. Four different starting positions of the slit in the line bisection task (far-left, mid-left, mid-right, far-right) were used to manipulate spatial attention. The arrows depict the direction of movement of the bisection slit. Note that the bisection task can only be solved when the subject attends the slit that bisects the horizontal bar.

damaged control patients did not receive visual treatments and were enrolled in the study before receiving any other neuropsychological treatment.

2.2. Clinical-neuropsychological tests

Handedness was determined in all subjects with the German version of the Edinburgh handedness inventory (Salmaso & Longoni, 1985) which measures hand preference. This is expressed as a laterality quotient ranging from –100 (=strongly left-handed) over 0 (=ambidextrous) to +100 (=strongly right-handed; results see Table 1). Visual letter acuity was measured separately for each eye with standardized, high-contrast letter charts (Fronhäuser, München, Germany) for the near (0.4 m) viewing distance in all 4 samples. Binocular visual fields were mapped with a Tübingen perimeter in all patients (for a detailed description see (Kuhn et al., 2010) results see Table 1). In short, dynamic visual perimetry was performed with a circular white target (luminance: 102 cd/m²; size: 1.02°) using a Tübingen bowl perimeter in a completely dark room. With the same perimeter, the extent of the visual search field – a measure of oculomotor capacity in the blind field – was measured (details in, Kerkhoff et al., 1994). The subject was instructed to search with saccadic eye movements for a circular white target (size: 1.02°, luminance: 102 cd/m²) that was moved by the perimetrist along every meridian from the periphery to the centre with a speed of 2°/s. The sequence of the meridians tested was random. The patient presses the response key as soon as she/he detects the target. This position is scored as the eccentricity of the search field (in°). Here, we indicate the average of the search field of all 6 meridians lying in the blind hemifield; the lower normal cutoff is 30° (Kerkhoff et al., 1994).

Five conventional visual neglect tests – comparable to the Behavioural Inattention Test (Wilson, Cockburn, & Halligan, 1987) – were performed to rule out visual neglect in our HA samples and document visual neglect in the 3 additional patients with neglect: horizontal line bisection of a 20 cm × 0.2 cm black line on a white sheet of paper; number cancellation (30 targets among 150 distracters, presented on a 29.7 cm × 21 cm large white paper), drawing of a clock face from memory, copying 3 geometrical figures (a star, a daisy, a face; each on a different sheet of paper) and an indented reading test of 180 words. Neglect was diagnosed when the truncation midline in bisection deviated more than 5 mm to the ipsilesional side (Kerkhoff, 1993), when more than 1 target was omitted on one side in number cancellation, when numerals were omitted or misplaced on the left side of the clock face test, or when the subject committed more than 2 reading errors in the indented reading test (Reinhart, Schindler, & Kerkhoff, 2011). None of the 3 patient groups (HA samples, BD control group) showed any signs of visual neglect in any of the 5 neglect screening tests.

Visual perimetry and visual search field testing as well as the experimental line bisection testing were performed in a totally darkened room (<10 Lux room lighting), the only visible stimulus in perimetry and search field testing was the background illumination of the perimeter (3.2 cd/m²) and the test stimulus. In line bisection tests the only visible stimulus was the horizontal, white bar on the black computer screen. All other (screening) tests took place in a day-lit room (mean lighting: approximately 400 Lux).

2.3. Computerized horizontal line bisection task

Subjects were placed in front of a computer screen (17") in a distance of 0.45 m. The head was positioned in a head- and chinrest mounted on a table in front of the screen to prevent head movements during testing. On the screen a white horizontal bar (160 mm × 10 mm, luminance: 100 cd/m²) appeared centrally on the black screen. The bar contained a vertical slit (size: 5 mm × 10 mm) that appeared – in different experimental conditions – either on the far left end of the bar, in a mid-left position, in a right-mid position or on the far-right position of the bar (Fig. 1). The subject was asked to determine verbally when the slit was exactly in the centre of the horizontal bar. To this purpose the examiner moved the slit via the software program (Kerkhoff & Marquardt, 2004) in steps of 1 mm slowly towards the other side of the bar until the subject indicated that the slit was exactly in the middle of it. To

Table 1

Patient data: L1–L10: left Homonymous Hemianopia; R1–R10: Right Homonymous Hemianopia; C1–C10: brain damaged control patients.

No.	Age (yrs) Sex	Aetiology TSL (months)	Lesion side localization	Visual acuity near LE/RE (%)	Visual field sparing (°)	Visual search field (°)	Handed-ness
L1	69/f	CVI/120	R-occ	50/60	2	35	+100
L2	40/f	CVI/10	R-occ	100/100	14	66	+100
L3	71/m	CVI/24	R-occ	90/–	4	15	+100
L4	63/m	CVI/13	R-occ	60/50	2	25	+100
L5	32/f	CVI/9	R-occ-temp	60/50	1	30	+100
L6	31/f	CVI/2	R-par-temp	125/125	1	10	+100
L7	33/m	CVI/168	R-occ-temp	100/100	2	10	+100
L8	56/m	SHT/5	R-par-temp	90/50	4	42	+100
L9	32/m	CVI/96	R-temp	90/90	1	30	+100
L10	32/m	CVI/48	R-occ-temp	100/100	2	38	+100
Mean	45.9/–	–/49.5 Md: 13	–	86.5/80.6	3.3° Md: 2	30.1	+100

No.	Age (yrs)Sex	AetiologyTSL (months)	Lesion side localization	Visual acuity near LE/RE (%)	Visual field sparing (°)	Visual search field (°)	Handed-ness
R1	44/f	CVI/15	L-occ-temp	70/70	5	22	+33.3
R2	66/m	CVI/4	L-occ-temp	80/80	15	42	+100
R3	42/m	CVI/36	L-occ-temp	80/80	20	55	+60
R4	48/m	CVI/38	L-occ-temp	80/80	3	44	+100
R5	44/m	Tu/11	L-occ-temp	80/80	5	34	+100
R6	58/m	CVI/7	L-occ	90/90	4	28	+100
R7	33/m	Tu/19	L-par-occ	100/100	6	45	+100
R8	69/m	CVI/3	L-occ	80/70	2	8	+100
R9	62/m	CVI/17	L-occ	100/60	5	10	+100
R10	39/f	CVI/3	L-occ	125/30	3	26	+100
Mean	50.5/–	–/15.3 Md:9	–	88.5/74.0	6.8° Md: 5	31.4	+89.3

No.	Age (yrs) Sex	Aetiology TSL (months)	Lesion side localization	visual acuity near LE/RE (%)	Handedness
C1	46/m	Enceph./4	L-temp	100/100	+100
C2	55/m	Sepsis/10	Diffuse	120/120	+100
C3	49/m	CVI/10	Diffuse	90/90	+100
C4	55/m	CVI/50	L-BG	–/63	+100
C5	47/m	CVI/15	L-BG	100/100	+100
C6	63/m	CVI/2	L-temp	120/120	+100
C7	59/m	CVI/3	R-front-temp	100/100	+100
C8	48/m	CVI/8	L-temp	100/80	+100
C9	63/f	CHI/34	Diffuse	100/70	+100
C10	42/f	CVI/14	L-temp	100/100	+100
Mean	52.7/–	–/15.0 Md:10	–	103.3/94.3	+100

Legend: m/f, male/female; LE/RE, left/right eye; L/R, left/right; Enceph, encephalitis; BG, basal ganglia, Tu, tumour operated; CVI, cerebrovascular insult; CHI, closed head injury; TSL, time since lesion onset in months; L/R, left/right; occ, occipital, par, parietal, temp, temporal.

ensure patients were fixating the gap during each bisection trial the experimenter asked every subject when starting a bisection trial whether he/she could see the gap on the left/right side of the bar and how it changed position according to the verbal commands of the subject to the experimenter. The experimenter checked regularly when moving the gap along the bar whether the subject re-fixated the new position of the gap within the bar. However, no eye tracking control was adopted to measure quantitatively whether the subject's eye in fact fixated the gap.

Ten trials were performed within each of the 4 cueing tasks; 5 trials were performed en block with the gap starting from the left side and 5 trials were performed en block with the gap starting from the right side of the bar. This resulted in a total of 10 trials per cueing task. The sequence of the blocks was counterbalanced. Constant errors were computed using the method of limits by special software (Kerkhoff & Marquardt, 1998, 2004) between the objective centre of the bar and the mean position of the slit as determined by the subject. No motor component was involved in this bisection task on the subject's side, nor was there any time limit for the subjects.

3. Results

3.1. Comparison of the samples

Statistical comparisons revealed that neither handedness ($[F(3, 36) = 1.47; p = 0.24]$), nor age ($[F(3, 18.78) = 1.22; p = 0.33]$), nor gender $[X^2(3, n = 40) = 2.88, p = 0.41]$ were significantly different between the four samples. Visual acuities for the near viewing distance (0.4 m) were examined separately for the left and the right eyes. There were no significant differences between the

three patient groups ($[F(2, 26) = 2.59; p = 0.9]$ for the left eye; $[F(2, 26) = 2.16; p = 0.14]$ for the right eye).

Moreover, the three patient groups did not differ significantly regarding time since lesion (median left HA = 18.50 months; median right HA = 13.00 months, median control patients = 10 months; $[F(2, 16.12) = 1.62; p = 0.23]$).

3.2. Visual field sparing and saccadic search field

Both hemianopia (HA) samples did not differ significantly from each other in visual field sparing (mean left HA = 3.3° ; mean right HA = 6.8° ; $T(18) = -1.57, p = 0.135$). One out of ten left-sided HA patients showed a visual field sparing of 14° . Among the right-sided HA sample one patient had a field-sparing of 15° , the second of 20° . Visual search field in the blind field did not differ significantly between the two HA groups (mean left HA = 30.1° ; mean right HA = 31.4° , $T(18) = -0.18, p = 0.86$). Saccadic search field did not correlate significantly with the HLBE (Spearman correlations: $Rho = -0.072, p > 0.05$, two-tailed).

3.3. Spatial cueing direction in hemianopic patients and control subjects

The vertical slit was moved by the experimenter towards the middle of the bar, starting at different positions (far-left,

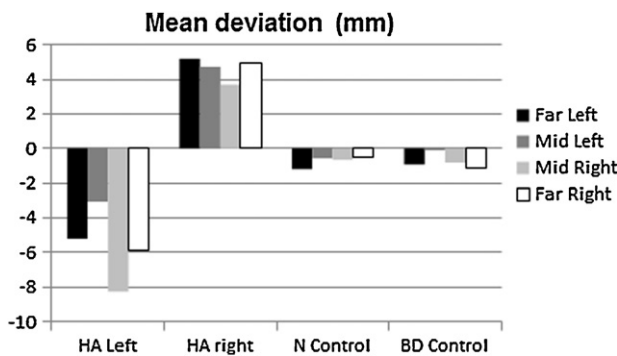


Fig. 2. Mean deviations (signed errors, in mm) of the four experimental groups in the 4 line bisection tasks. Negative or positive deviations illustrate leftward or rightward deviations from the physical midline of the line. HA left/right: left vs. rightsided hemianopia; N Control/BD Control: normal control subjects vs. brain damaged control subjects.

mid-left, mid-right, far-right). To examine if there was a possible “cueing” effect due to these starting positions, an ANOVA with the factors group (HA left, HA right, normal control, and BD control) and starting position was computed. There was no main effect of starting position [$F(3, 108) = 1.76, p = 0.16$] and also no significant group $\times$ starting position interaction [$F(9, 108) = 0.92, p = 0.51$]. The significant effect of group [$F(3, 36) = 61.58, p < 0.001$] indicated the expected line bisection deviation error of HA patients to the *contralesional*, blind field (leftwards in left HA, rightwards in right HA; Fig. 2). Subsequent comparisons revealed significant differences between the HA groups and the two control groups [left HA: $T(36) = -7.46, p < 0.001$; right HA: $T(36) = 8.23, p < 0.001$], but no significant difference between the two control groups (mean difference = 0.015 mm, $p = 0.948$). Both control groups showed the expected pseudoneglect [normal control: mean leftward shift = -2.92 mm, $T(9) = -1.98, p = 0.039$; BD control: mean leftward shift = -2.98 mm, $T(9) = -1.75, p = 0.055$, see Fig. 2].

3.4. Spatial cueing in relation to lesion anatomy

Although we found no evidence of spatial cueing in line bisection in our hemianopic patients (see Section 3.3 above), this effect might theoretically be due to a mixture of a subgroup of patients who indeed may have responded to cueing and those who did not respond. One interesting modulating variable in this context that may have influenced cueing differentially is lesion anatomy. As we know that cueing in neglect patients with temporo-parietal lesions is very effective it might be hypothesized that cueing might also work better in HA patients with lesions beyond the occipital lobe, i.e. temporo-occipital lesions. As some of our hemianopic patients had pure occipital lesions while others had lesions including occipital brain areas but extending beyond the occipital lobe (in most cases into the temporal cortex), the nonsignificant effect of spatial cueing thus may have been due to a mixture of these two subgroups. To examine whether the bisection errors were different in these two subgroups (irrespective of the side of hemianopia), an ANOVA with the factors group (occipital lesion versus extended lesion) and starting position (far-left, mid-left, mid-right, far-right) was computed on the unsigned HLBE. Again, there was no main effect of group [$F(1, 108) = 0.166, p = 0.689$], no main effect of starting position [$F(3, 54) = 0.142, p = 0.884$], and no significant group $\times$ starting position interaction [$F(3, 54) = 0.668, p = 0.530$]. Hence, no differential influence of lesion anatomy was found on the HLBE under the four different cueing conditions. Fig. 3 summarizes the results.

3.5. Spatial cueing direction in neglect patients

The single data from the 3 neglect patients were collapsed for each task and analyzed with nonparametric statistics across the 4 spatial cueing task conditions. A Friedman-test revealed a highly significant difference between the 4 task conditions ($\chi^2 = 28.45, df = 3, p < 0.001$). Subsequent paired comparisons with Wilcoxon-tests revealed significant differences between the following task/cueing conditions: Far-Left vs. Mid-Right ($z = -3.297, p < 0.001$); Far-Left vs. Far-Right ($z = -3.408, p < 0.001$); Far-Right vs. Mid-Right ($z = -2.728, p < 0.001$), and Mid-Left vs. Far-Right ($z = -3.448, p < 0.001$). All other comparisons did not reach statistical significance (largest z -value: -1.023 , smallest $p = 0.306$). In summary, four of the 6 possible statistical comparisons between the 4 spatial cueing conditions revealed a highly significant effect of the cue position on line bisection performance. In general, leftward cue positions were associated with a leftward shift in line bisection, whereas more rightward cue positions led to a more rightward shift in line bisection as compared to the more leftward starting positions of the cue (see Fig. 4, averaged results on the right side).

4. Discussion

Our study revealed clearly, that 4 different manipulations of spatial cueing had no significant effect at all on the HLBE. As the starting point of the slit which served to bisect the horizontal bar on the computer screen did not induce any effect on the HLBE, it was obviously irrelevant. Hence, neither did patients with left or right HA benefit from such a spatial cue that must be attended because otherwise the subject cannot perform the bisection task, nor did their performance deteriorate in the opposite cue condition. It might be conjectured that this was simply because our spatial cueing manipulation was ineffective. However, the very same manipulation revealed significant spatial cueing effects in the 3 patients with leftsided HA and left visuospatial neglect (Fig. 4). These cueing effects were significant for 4 out of 6 possible comparisons between the 4 cueing conditions, thus showing a strong effect of the slit position on bisection performance despite the small group of neglect patients. In general, the final bisection performance revealed a clear covariation with the initial starting position of the slit. Put differently: the more leftward the cue position, the more leftward the bisection and vice versa. These observed spatial cueing effects in our 3 neglect patients are largely compatible with earlier findings – though achieved with different experimental manipulations – showing that a leftsided (contralesional) cue in the neglected hemispace (a letter, a hand movement or a moving stimulus, see below) typically shifts bisection towards the cue while a cue on the right (ipsilesional) side of the horizontal bar shifts bisection towards this cue was either ineffective or even deteriorated performance (Butter et al., 1990; Lin et al., 1996; Riddoch & Humphreys, 1983).

Our null-finding of spatial cueing in chronic HA (without neglect) may be surprising at first glance given that *repetitive* visual attention training is clearly effective as a treatment for the visual search disorder of HA patients (Lane et al., 2010), and in light of the robust effects of the same spatial-attentional cues on line bisection in visual neglect. However, a recent study by Baier et al. (2010) found the HLBE in acute and chronic HA indicating no emergence as a kind of compensatory behaviour that facilitates attentive orienting to the blind field. Together, their and the current findings suggest that the HLBE in chronic HA is not the consequence of hyperattention to the blind or hypoattention to the intact visual field. Rather, the lesion data of Baier et al. (2010) and Zihl et al. (2009) suggest that the HLBE is unlikely of attentive origin, but reflects a kind of spatial-perceptual error to the contralesional side,

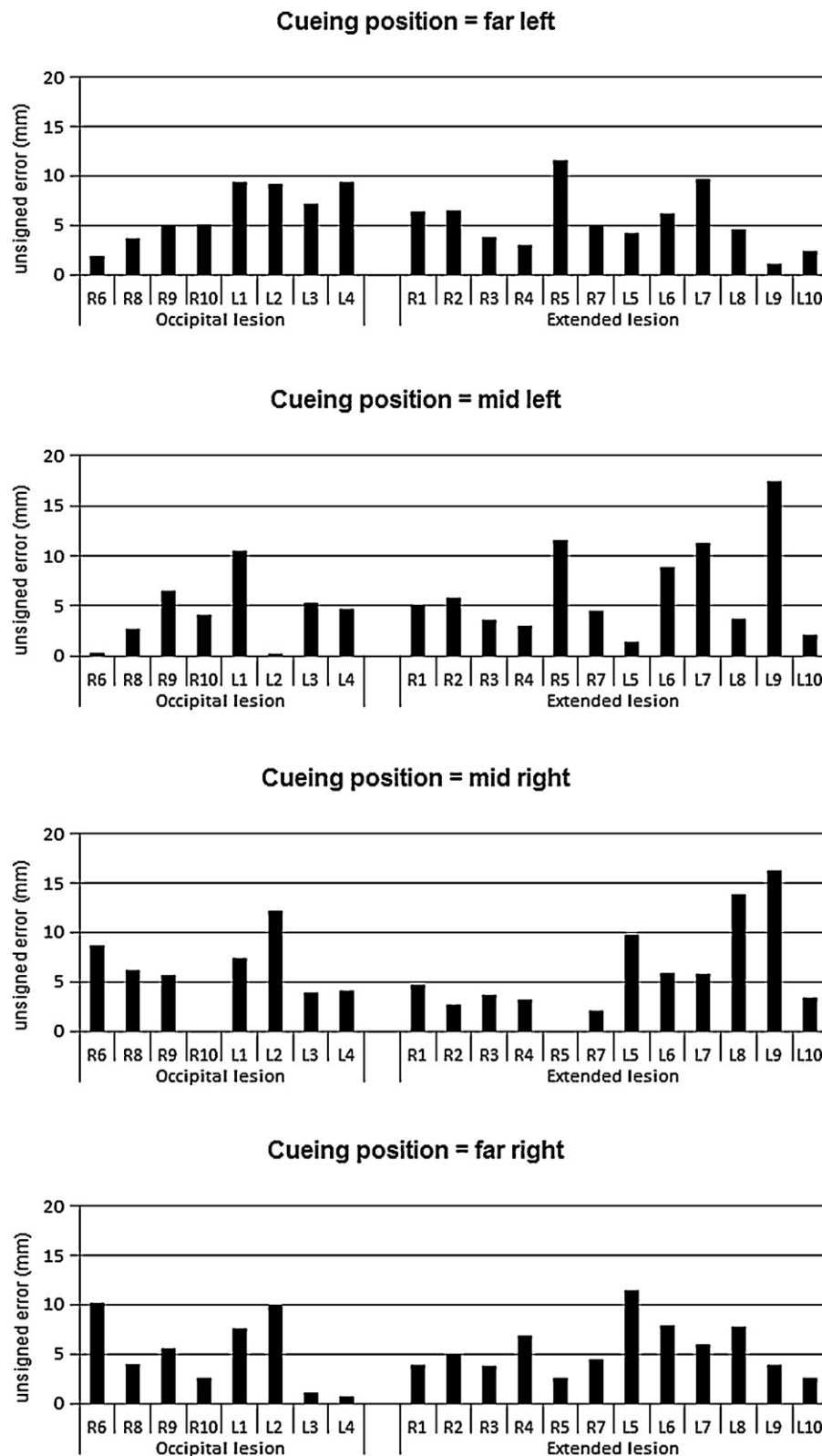


Fig. 3. Mean unsigned line bisection errors (in mm) in the 4 spatial cueing conditions during line bisection (see Fig. 1), shown separately for patients with pure occipital lesions vs. patients with lesions extending beyond the occipital lobe (extended lesions). Note that left and right hemianopic patients were collapsed into the two lesion subgroups irrespective of the side of hemianopia. Positive deviations indicate bisection errors towards the blind field.

that emanates early in the course of hemianopia and may persist for a long time. Moreover, the comparable size of the HLBE in acute and chronic HA patients in the Baier et al. (2010) study argues against the gradual development of the HLBE in terms of a

compensatory phenomenon. Furthermore, the null-effect of spatial cueing as analyzed in different lesion subgroups of our hemianopic patients suggests that the HLBE is a robust phenomenon that is not as easily modulated as its counterpart in patients with left-sided

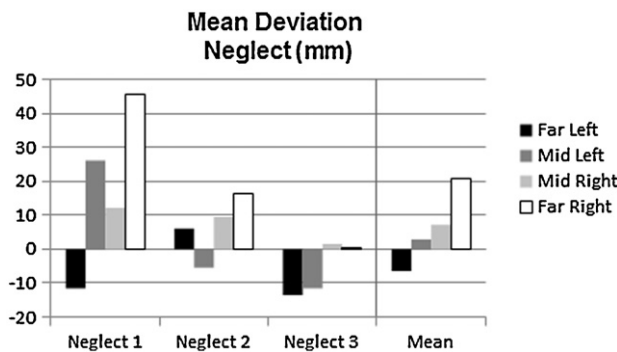


Fig. 4. Mean deviations of 3 patients with leftsided visual neglect and leftsided hemianopia in the line bisection task under four different cue conditions (see Fig. 1). Note the different scaling of the y-axis as compared to Fig. 2, due to the large cueing effects in the 3 patients. Same convention of deviations as in Fig. 2.

hemianopia plus neglect (as shown in Fig. 4 of our study). Taken together, all these accumulated findings render an explanation of the HLBE in terms of facilitating attentive orienting towards the blind field unlikely. Obviously, the HLBE does not “serve” a better compensation of the field loss as implicitly assumed in early theories (Gassel & Williams, 1963) or more explicitly stated in recent explanations (Mittra, Abegg, Viswanathan, & Barton, 2010). More specifically, according to the current results spatial attention does not seem to play a major role in the maintenance of the HLBE in chronic hemianopia. Rather, the HLBE represents a type of visuospatial disturbance that immediately follows after lesion to some extrastriate cortical areas.

Finally, a very early account of the HLBE can be rejected as well. The German vision researcher Poppelreuter (1922) suggested that HA patients develop a new “pseudofovea” located some degrees in the contralesional, blind field. Although he did – to our knowledge – not explicitly state that the HLBE and the “pseudo-fovea” might be connected as both represent a contralesional spatial shift towards the scotoma, it is tempting to assume that both might be co-related. More recent studies (Trauzettel-Klosinski, 1997) have supported this notion with their finding of a small fixational shift to the blind field which according to their interpretation facilitates reading. We recently tested the eccentric-fixation hypothesis (Poppelreuter, 1922) as a potential explanation of the HLBE explicitly by blind spot mapping of the ipsilesional eye in 20 HA patients, 10 non-hemianopic, but brain-damaged control patients and 10 healthy individuals (Kuhn et al., 2012). Importantly, the position of the blind spot was in the normal range in 38 of 40 tested subjects, did not differ significantly between hemianopic and nonhemianopic groups, and did not correlate significantly with the HLBE which was present in all 20 HA patients. Moreover, the HLBE showed no significant correlation to the capacity of the HA subjects to explore their blind field with scanning eye movements (“visual search field”) which might have been expected if the HLBE reflects a compensatory orienting of eye movements to blind field. Together, these recent results show that eccentric fixation plays no major role in the emergence of the HLBE. The same conclusion was reached for the contralesional, oblique error in the subjective visual straight ahead observed in 15 non-neglecting patients with homonymous quadrantanopia, which was not accompanied by any abnormality of horizontal or vertical eye position as determined by blind spot mapping (Kuhn et al., 2010). Moreover, visual scanning capacity in the blind field and the size of the HLBE towards the blind field are unrelated phenomena, suggesting that the HLBE represents an independent, third feature of HA patients besides their well-established visual exploration deficits and hemianopic alexia.

Despite our clear results, some caveats have to be mentioned. Firstly, other types of spatial cueing, i.e. local or global visual motion

cues, which effectively modulate line bisection and other visuospatial deficits in patients with spatial neglect (Schindler & Kerkhoff, 2004), may be more effective in manipulating spatial attention in HA, and in turn may influence the HLBE. Secondly, cues from another modality (acoustic, haptic) may prove more effective than cues delivered in the same – “impaired” – visual modality. Thirdly, spatial cueing may be very well effective in acute hemianopia, when the patients try to adapt to the sudden field loss (Machner et al., 2009), and develop compensatory strategies. This effect may have vanished after 9–12 months, when most of our patients were examined. This has to be tested in subsequent studies. Finally, repetitive spatial-attentional training instead of transient spatial cueing – such as recently employed elegantly in attention therapy for HA as a treatment for the visual search disorder (Lane et al., 2010) – may indeed reduce the HLBE transiently or even permanently. These are future issues that may help us to better understand the nature of the HLBE and the mechanisms of recovery from HA and associated visuospatial disorders. Finally, solving these issues may in the future lead to an effective treatment of the HLBE in HA which is at present not within reach.

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