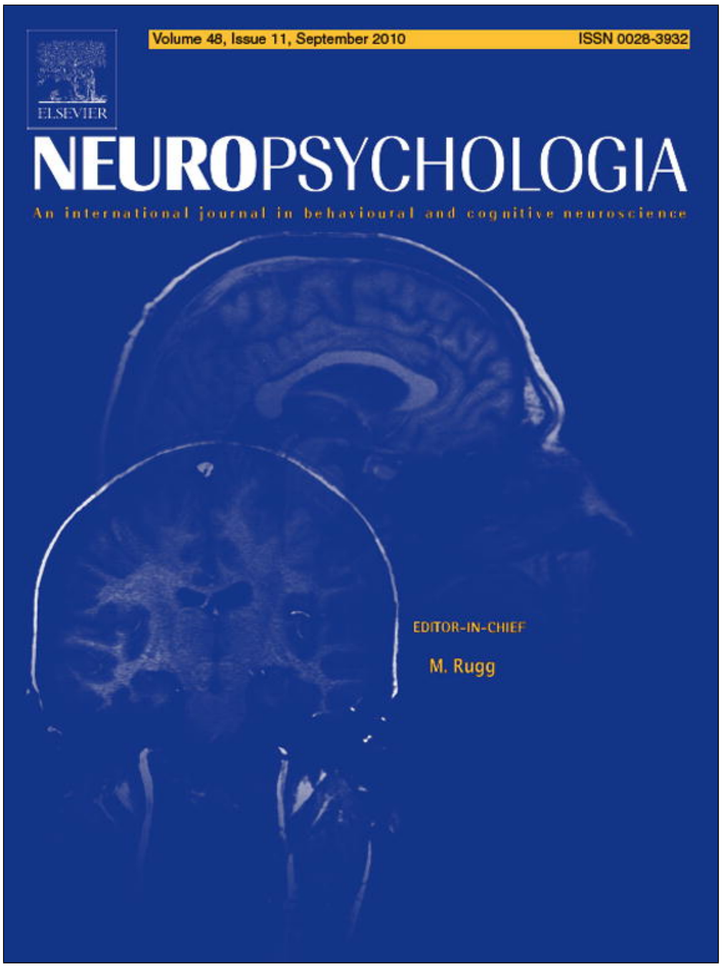
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Oblique spatial shifts of subjective visual straight ahead orientation in quadrantic visual field defects

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ABSTRACT

Patients with postchiasmatic visual field defects often show a contralesional bias towards the scotoma in line bisection or when indicating their visual subjective straight ahead (VSSA). Recent evidence suggests a retinotopic misrepresentation of visual space in patients with homonymous quadrantanopia (HQ). We therefore assessed in the present study whether patients with HQ show an oblique shift of their VSSA towards their scotoma, in addition to the known bias in horizontal line bisection. Moreover, we examined whether eccentric fixation contributes to this shift. To this purpose, 15 non-neglecting stroke patients with HQ and 15 matched healthy control subjects were assessed in horizontal line bisection and in the horizontal and vertical dimension of their VSSA. Additionally, perimetric blind spot mapping was performed. Eight out of nine patients with left quadranopia showed the typical leftsided, horizontal line bisection error, while only one out of seven patients with rightsided quadranopia showed a rightsided shift. Normal subjects showed a non-significant leftward shift in line bisection (pseudoneglect). All 15 patients with HQ showed a large oblique shift of their VSSA towards the blind quadrants, while normal subjects showed no systematic left-rightward shift, but a small downward shift of the VSSA. The position of the blind spot was normal in all testable eyes of patients and control subjects, thus excluding eccentric fixation or cyclorotation of the eyes. In conclusion, our study reveals a hitherto unreported oblique spatial shift of subjective visual body orientation towards the blind quadrants in non-neglecting patients with quadranopia.

1. Introduction

Homonymous hemianopia is a frequent sequel after stroke (Schofield & Leff, 2009). Hemianopic patients frequently show a peculiar spatial error besides their impairments in reading (Schuett, 2009) and visual scanning (Hildebrandt, Giesselmann, & Sachsenheimer, 1999; Machner et al., 2009b) termed the “hemianopic line bisection error”. Axenfeld who coined this term (Axenfeld, 1894) reported that most of his hemianopic patients misplaced the midpoint towards their blind field when bisecting a horizontal line on a sheet of paper. Later investigators have in general confirmed Axenfeldĭs early observations (Kerkhoff & Bucher, 2008). Moreover, a recent large-scale patient study has shown that this horizontal spatial error is found in all types of unilateral visual field defects, not only hemianopia (Schuett, Dauner, & Zihl, in press). Until now, most often *horizontal* deviations in line bisection (Barton & Black, 1998; Doricchi et al., 2005; Hausmann, Waldie, Allison, & Corballis, 2003; Zihl, Sämann, Schenk, Schuett, & Dauner, 2009) or in the visual subjective straight ahead orientation (Ferber & Karnath, 1999) have been studied although vertical shifts in altitudinal hemianopia have also been reported (Kerkhoff, 1993). While hemianopic patients without neglect show a contralesional, horizontal shift of the subjective visual straight ahead towards the blind field (Ferber & Karnath, 1999) patients with visual neglect – with or without concurrent field defect – often show large ipsilesional shifts of 10–30° (Schindler & Kerkhoff, 2004; Schindler, Kerkhoff, Karnath, Keller, & Goldenberg, 2002).

An open question is whether quadrantic visual field defects – a “hallmark” of extrastriate visual cortex lesions (Horton & Hoyt, 1991) – also follow this pattern of results. Schuett et al. (in press) in their recent study reported that patients with upper or lower homonymous quadrantanopia (HQ) without visual neglect also show the typical *horizontal* line bisection error akin to that seen in patients with left- or right-sided hemianopia (but see Machner, Sprenger, Hansen, Heide, & Helmchen, 2009a). However, this may not be the only spatial bias that patients with HQ show. Doricchi and co-workers (Doricchi, Guariglia, Figliozzi, Magnotti, & Gabriele, 2003) recently reported a striking, retinotopic dependency of spa-

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tial misrepresentation in a patient with left lower and incomplete upper quadrantanopia with mild neglect. This patient misjudged visual distances displayed along different meridians in his blind quadrants. This finding suggests, that patients with HQ may show additional visuospatial misrepresentations beyond those found in the horizontal (left–right) dimension in line bisection.

Moreover, it is known that the hemianopic spatial bias in line bisection is often directed towards the greatest defect in the scotoma: horizontally in left- or right-sided hemianopia (Barton, Behrmann, & Black, 1998; Barton & Black, 1998) and a combination of vertical and horizontal deviations in patients with altitudinal and lateral visual field defects (Kerkhoff, 1993). If this also applies to HQ, such patients might be expected to show an oblique spatial bias towards their blind quadrant(s), in addition to their *horizontal* spatial bias documented previously in horizontal line bisection (Schuett et al., in press).

Furthermore, an interesting though largely unexplored question is the possible role of eccentric fixation in the emergence of the spatial error in line bisection or in the subjective visual straight ahead. Eccentric fixation has been occasionally reported in hemianopia (Fuchs, 1922; Teuber, Battersby, & Bender, 1960; Trauzettel-Klosinski, 1997), and discussed as a possible adaptive strategy to compensate for the field loss (Fuchs, 1922; Trauzettel-Klosinski, 1997). As the fixational shift and the line bisection error in hemianopia both are typically directed towards the blind field both might be (cor)related, or eccentric fixation even might cause or exaggerate the spatial shift observed in line bisection. However, bisection judgments, straight ahead judgments and fixation measures were not studied in parallel in these previous studies. In the present study we investigated the judgment of the VSSA in the horizontal and vertical dimension in 15 patients with perimetrically documented HQ, without any sign of visual neglect, and in 15 matched healthy control subjects with perimetrically intact visual fields. Horizontal line bisection was also tested in order to compare the findings in line bisection and the VSSA. In addition, blind spot mapping was performed to explore the role of eccentric fixation.

2. Methods

2.1. Subjects

Fifteen patients (11 male, 4 female, mean age: 50.1 years, sd: 10.4) with unilateral HQ after unilateral stroke ($n = 12$) or haemorrhage ($n = 3$) were investigated. None of the 15 patients had visual neglect as determined by five conventional tests (Table 1). All patients had a corrected binocular visual acuity of >0.80 for the near (0.4 m) and far (6 m) viewing distance. Fifteen matched healthy control subjects (9 male, 6 female) with normal visual acuity (>0.80 decimal acuity for the near and far) and perimetrically intact visual fields were recruited (mean age: 45.8 years, range: 18–67). All patients and controls were right-handed according to their verbal report. Neither age (Mann–Whitney–Test, $U = 92$, $z = 0.395$, $p > 0.05$), nor gender ($X^2 = 3.3$, df = 1, $p > 0.05$) differed significantly between both samples. All HQ patients were aware of their field defect when asked during the perimetric session, thus excluding anosognosia for their field defect (Celesia, Brigell, & Vaphiades, 1997). None of the patients showed hemiparesis or hemiplegia, and all showed good verbal comprehension of the instructions.

2.2. Visual perimetry

Kinetic monocular perimetry was performed in all subjects with a Tuebingen perimeter (Aulhorn & Harms, 1972; Kerkhoff, Münβinger, & Meier, 1994) with a bright white stimulus (size: 106 inches, luminance: 102 cd/m^2), a grey stimulus (106 inches, 1.02 cd/m^2), a coloured target (green 525 nm, same size, 320 cd/m^2), and a form target (white light, same size, rhomboid, 320 cd/m^2). Kinetic perimetry was performed along all meridians in a pseudorandom order. Visual field sparing was determined for the oblique meridian within the blind quadrants (and is indicated in Table 1). Blind spot mapping was performed (monocularly) with a small 35 inches circular target (white light, 102 cd/m^2) in both eyes where possible (13 patients), or in the ipsilesional eye only (2 patients). The geometric centre of the blind spot of each eye was used for statistics and compared with normative values from the literature (Bixenman & von Noorden, 1982; Gradle & Meyer, 1929). Furthermore, the visual search field, a measure of oculomotor compensation in the visual field, was investigated with the same perimeter in the blind and intact, mirror-

Table 1
Clinical and demographic data of 15 patients with homonymous quadrantanopia (HQ) without visual neglect.

Patient	Age/sex	Etiology	Lesion localiz.	Months since lesion	Quadrantic field defect, field sparing (°)	Awareness of scotoma	Size of visual search field (blind/intact quadrant,°)	ND	Figure copy left/right side	Cancellat. omissions left/right side	Spatial problems (staircase)
1	48, f	R-ICB	T	4	Left upper, 1	Yes	34/68	no	+/+	0/0	0
2	60, m	R-MCA	T, BG	2	Left upper, 2	Yes	33/73	no	+/+	0/0	0
3	45, m	R-PCA	O–T	1	Left upper, 2	Yes	39/72	no	+/+	0/0	0
4	38, m	R-MCA	P	3	Left lower, 6	Yes	46/68	no	+/+	0/0	1
5	51, f	R-MCA	P	2	Left lower, 32	Yes	34/68	no	+/+	0/0	1
6	57, f	R-ICB	P	2	Left lower, 22	Yes	37/70	no	+/+	0/0	1
7	25, m	R-MCA	P–O	13	Left lower, 28	Yes	38/62	no	+/+	0/0	1
8	50, m	R-PCA	P–O	5	Left lower, 10	Yes	34/68	no	+/+	0/0	1
9	58, m	R-MCA	P	5	Left lower, 32	Yes	38/70	no	+/+	0/0	1
10	45, m	L-MCA	T	7	Right upper, 3	Yes	35/60	no	+/+	0/0	0
11	55, m	L-MCA	T	5	Right upper, 5	Yes	40/60	no	+/+	0/0	0
12	42, m	L-MCA	T	4	Right upper, 2	Yes	45/60	no	+/+	0/0	0
13	54, f	L-ICB	O–P	3	Right lower, 4	Yes	33/70	no	+/+	0/0	1
14	69, m	L-MCA	P–T	4	Right lower, 28	Yes	30/65	no	+/+	0/0	1
15	55, m	L-PCA/MCA	O–P	3	Right lower, 28	Yes	33/60	no	+/+	0/0	1
Mean ($N = 15$)	50.1 (25–69)		–	4.2 (1–13)	13.6 (1–32)		36.6°/66.3°	0/15	–	0/0	9/15

Abbreviations: MCA/PCA: middle/posterior cerebral artery infarction; ICB: intracerebral bleeding; L/R: left/right; Lesion: F – Frontal; P – parietal; T – temporal; O – occipital; BG: basal ganglia; visual acuity: decimal letter acuity for near (0.4 m) and far (6 m) viewing condition; visual field: field sparing is indicated in (°) for the oblique meridian in the blind quadrant. Awareness of visual field defect: patient reports visual field defect during the anamnesis when asked by the experimenter; spatial problems: indication of subjective problems (Score 1) or no subjective problems (Score 0) in negotiating a staircase up-/down-wards when asked in the anamnesis. *Neglect screening tests:* visual search field: normal cutoff: 30°; ND = neglect dyslexia: 180 word reading test, cutoff: max 2 errors, yes/no: neglect dyslexia present/absent; figure copy: – = omissions or distortions; + = normal performance; cancellation: number of omissions per hemispace, normal cutoff: max 1 per hemispace

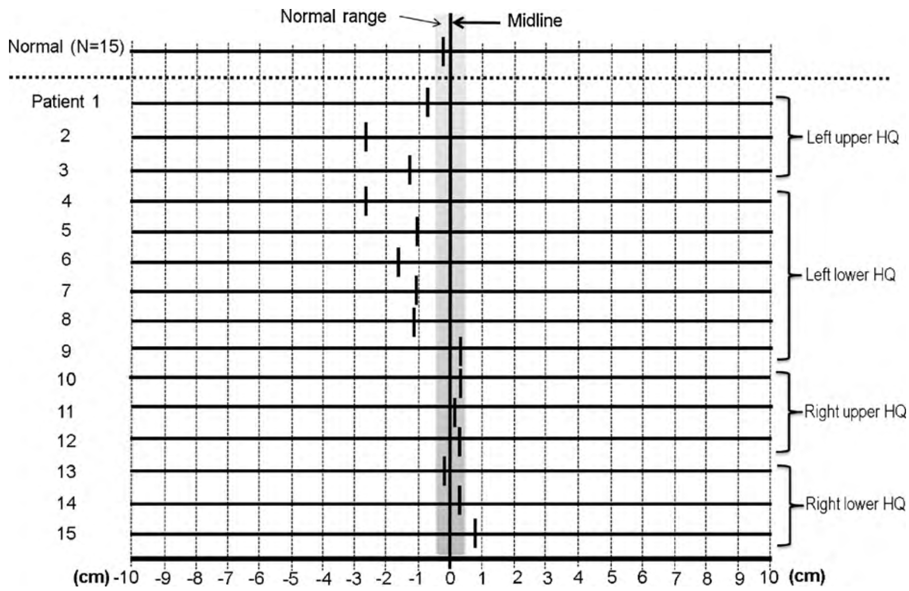

Fig. 1. Individual results in horizontal line bisection (deviations in cm from the true midline position (0)) in all 15 patients with homonymous quadrantanopia (HQ) and mean deviation in the 15 normal control subjects tested. HQ: homonymous quadranopia. The shaded area indicates the total range of performance in the 15 normal control subjects.

symmetric quadrants (details see (Kerkhoff et al., 1994)). The subject is instructed to search with saccadic eye movements for a circular white target (size: 106 inches, luminance: 102 cd/m^2) that is 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 pressed the response key as soon as the target was detected. This position is scored as the eccentricity of the search field (in°). Here, we selected the median of the search field values of the meridians lying in the *blind* quadrants and compared it with the median of those values obtained in the mirror-symmetric *intact* quadrant. A minimum search field size of 30° in every quadrant is the normal cutoff (Kerkhoff, 1999), and was applied to all HQ patients as a necessary condition for inclusion in the sample to ensure that they were able to detect the test stimulus in the VSSA test at this eccentricity in all four quadrants (see below).

2.3. Visual neglect tests

Visual neglect was tested with five conventional tests, four of them very similar to those of the Behavioural Inattention Test (Halligan, Marshall, & Wade, 1989; Wilson, Cockburn, & Halligan, 1987): visual search field in the blind and intact quadrants (see above); horizontal line bisection (20 cm × 0.5 cm long, black horizontal line), cancellation of numerals (30 targets in 200 distracters, 15 in each hemifield), clock drawing from memory, and figure copy (star, flower, cube). Horizontal line bisection was tested conventionally in 3 separate trials with a black horizontal line (20 cm × 0.5 cm) presented horizontally on a white sheet of paper. All patients used their ipsilesional hand for placing the bisection mark. The median of the 3 trials was used for statistics.

Visual search field is significantly reduced in the neglected hemifield of patients with hemianopia and visual neglect (<10°, Kerkhoff, Münβinger, Haaf, Eberle-Strauss, & Stögerer, 1992) and is therefore a useful screening for visual neglect. All screening tests (including line bisection, but with the exception of the search field test) were shown on a 29.7 cm × 20 cm white paper board and at a distance of 0.33 m from the patientĭs eyes (for more details see Funk, Finke, Muller, Utz, & Kerkhoff, 2010).

2.4. Visual subjective straight ahead (VSSA)

The visual subjective straight ahead (VSSA) was tested in total darkness with the same perimeter as used for perimetry but all light sources were extinguished (background illumination and fixation spot). A small red spot (656 nm; 35 inches; 102 cd/m^2) was presented in one of the four quadrants. The subject was instructed to inform the examiner verbally, how to adjust the position of the spot until it was in the visual subjective straight ahead position, both in the horizontal and vertical dimension. Twenty trials were run, 5 each with a starting position from 30° eccentricity on the oblique meridian in the 4 quadrants (45°-meridian in the right upper quadrant, 135°-meridian in the left upper quadrant, 225°-meridian in the left lower and 315°-meridian in the right lower quadrant). Different starting positions were randomly intermingled in order to exclude effects of starting position on performance of the VSSA. The subject was positioned with his/her head and body positioned straight towards the centre of the perimeter. The head was fixed with a strap to the head and chinrest of the perimeter so that it remained central during all measurements. The median of the 20 trials was used for statistical analysis and is displayed in Fig. 1.

2.5. Statistics

Non-parametric statistics and one-sample *t*-tests were computed (SPSS, version 17). The adopted alpha-level was 0.05, two-tailed, corrected for the number of tests by Holmĭs procedure (Holm, 1979).

3. Results

3.1. Visual field and visual neglect testing

Table 1 summarizes the clinical and demographic patient data. All 15 patients had a homonymous quadrantic visual field defect with some degree of visual field sparing in the blind quadrant, a visual search field of at least 30° in their blind quadrant, good awareness of their visual field defect, and none showed visual neglect according to five conventional screening tests.

3.2. Horizontal line bisection

Fig. 1 shows the individual results of the 15 patients with HQ, and the mean performance of the 15 normal control subjects. Eight out of nine patients with leftsided HQ showed a significant, leftsided shift in horizontal line bisection, while only 1/7 patients with rightsided HQ showed the typical shift towards the blind quadrant. Analysis using *t*-tests confirmed that the group of patients with leftsided HQ deviated significantly from 0 to the left side (mean: – 14.22 mm, df = 8, $t = -4.349$, $p < 0.002$). In contrast, the patients with rightsided HQ showed a mean deviation of 2.66 mm to the right side, which was not significantly different from 0 ($t = 1.896$, df = 6, $p > 0.05$) and lay within the normal range (see Fig. 1). To test whether visual field sparing on the horizontal meridian within the blind field was related to this significant difference between the two groups of quadrantanopic patients we performed a comparison using independent *t*-tests. Mean visual field sparing on the horizontal meridian on the blind side was 54.3° (5–77°) in left quadranopia and 32.7° (5–78°) in right quadranopia. The difference is not significantly different ($t = 1.489$, df = 13, $p > 0.05$).

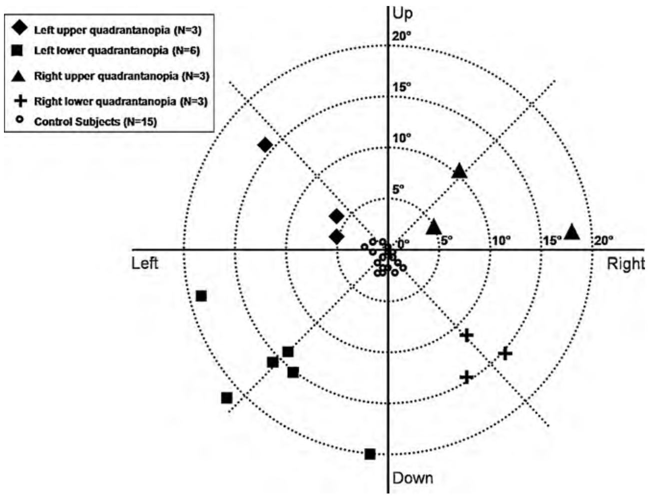

Fig. 2. Summary of individual results in all 15 patients with homonymous quadrantanopia (HQ) and 15 healthy control subjects in the visual subjective straight ahead task (VSSA, see text for details). The median of all 20 trials is displayed graphically for every subject. In addition, the complete range of the centres of the blind spots for the right and left eyes is shown for 13 patients and 15 control subjects. See detailed legend in the left upper part of the figure.

Moreover, field sparing on the horizontal meridian in the blind field was not significantly correlated in the 15 patients with the deviation in horizontal line bisection (Pearsonĭs r: -0.3, $p > 0.05$, Spearmanĭs $\rho = -0.27$, $p > 0.05$). The large field sparing on the horizontal meridian is due to the fact that in many patients the scotoma spared the horizontal meridian (which enabled us to measure the blind spot in so many patients.)

3.3. Visual subjective straight ahead (VSSA)

Fig. 2 shows the results of the VSSA judgments in both subject groups. All 15 HQ patients showed a significant shift of their VSSA towards their blind quadrant. In contrast, the judgments of all 15 healthy control subjects lay within ±2–3° around the true midpoint in the horizontal dimension, but were slightly shifted downwards in the vertical dimension (Fig. 2).

Unsigned errors were used for statistical analysis as the deviations in the different HQ subgroups were in different directions and therefore with different signs. The unsigned *horizontal* error in the VSSA was significantly greater in the HQ patients than in the control subjects (mean HQ: 11.6°, mean controls: 0.8°; Mann–Whitney–Test, $U = 2.5$, $p < 0.0001$). Likewise, the mean unsigned *vertical* error in the VSSA was significantly greater in the HQ patients than in the controls (mean HQ: 8.6°, mean controls: 1.6°; $U = 28.5$, $p < 0.0001$). Moreover, vertical ($t = 6.31$, df = 14, $p < 0.0001$) and horizontal ($t = 8.1$, df = 14, $p < 0.0001$) deviations of the VSSA were significantly different from the true midpoint (0°-position) in the HQ patients (one-sample t-test). Normal subjects did not differ horizontally in their VSSA from the true midpoint ($t = -1.24$, df = 14, $p > 0.05$), but showed a small, significant downward shift ($t = -3.56$, df = 14, $p < 0.003$). Vertical shifts of the VSSA were larger in patients with *lower* HQ ($N = 9$, mean: 11.1°) vs. *upper* HQ ($N = 6$, mean: 4.9°; $U = 7.5$, $p < 0.021$), and were largest in left lower HQ (mean: 12°, median: 10°, Fig. 1). No difference in *horizontal* shifts of the VSSA between upper and lower HQ emerged ($U = 26.5$, $p > 0.05$). Vertical shifts of the VSSA were significantly correlated (Kendallĭs r: 0.395, $p < 0.05$, one-tailed) with subjective problems in negotiating an up- or down-wards staircase (Table 1, right column), but horizontal shifts of the VSSA were not (r: 0.013, $p > 0.05$). Inspection of Table 1 shows that only patients with lower HQ acknowledged subjective problems in using stairs, especially downwards, but none of the patients with upper HQ did so. None of the 15 HQ patients was aware of the shift in the VSSA, although all were aware of their quadrantic field defect.

3.4. Intercorrelations of VSSA and horizontal line bisection

Spearman rank correlations (in the patients) between the *horizontal* line bisection and the *horizontal* error in the VSSA were highly significant ($r = 0.68$, $p < 0.01$, two-tailed), but the correlation between horizontal line bisection and the vertical error in the VSSA was not ($r = -0.08$, $p > 0.05$). The horizontal and vertical errors in the VSSA were not significantly correlated in the patients ($r = 0.08$, $p > 0.05$), nor in the healthy control subjects ($r = -0.28$, $p > 0.05$). Similarly, horizontal line bisection and the horizontal and vertical shift of the VSSA were not significantly correlated with each other (all Spearman correlation coefficients $p > 0.05$, n.s.).

3.5. Blind spot mapping

Blind spot mapping in both eyes was possible in 13/15 HQ patients (as a result of field sparing around the horizontal meridian) and in all 15 control subjects. The mean horizontal and vertical centre of the blind spot in the left and right eyes of both groups were as follows: HQ: left eye: horizontal: 15.1° lateral to the fovea, vertical: 0.9° below the horizontal meridian. HQ: right eye: 15.0° lateral to the fovea, vertical: 0.7° below the horizontal meridian. Controls: left eye: horizontal: 15.0° lateral to the fovea, vertical: 1.1° below the horizontal meridian; Controls: right eye: horizontal: 15.1° lateral to the fovea, vertical: 0.6° below the horizontal meridian (see Fig. 2). No significant differences were found in any of the paired comparisons with respect to the horizontal and vertical position of the blind spot centre in the right or left eyes of both samples (Mann–Whitney–Tests, smallest $p = 0.533$). Moreover, the position of the blind spot was in the normal range in all 13 patients and all 15 control subjects according to normative data (Bixenman & von Noorden, 1982; Gradle & Meyer, 1929). Hence, eccentric fixation was not present in any case and could not have contributed to the oblique shift of the VSSA in HQ. Moreover, the normal position of the blind spot in both eyes also rules out cyclorotation of the eyes.

4. Discussion

Patients with HQ – without any sign of visual neglect according to a battery of five conventional screening tests comparable to those of the Behavioural Inattention Test (Halligan et al., 1989; Wilson et al., 1987) and good awareness of their scotoma – show a significant (5–20°), oblique shift of their VSSA towards their blind quadrant. None of the patients was aware of this subjective shift, but the downward shift was related to subjectively reported problems in visual depth perception during walking up/downstairs. The shift of the VSSA is unlikely to result from insufficient scanning in the blind quadrants since visual search field size within the blind quadrants was within normal limits in all HQ patients (≥30°, Table 1). This is in agreement with recent findings in simulated hemianopia where the artificially created field defect impaired eye movements during ocular line bisection, but did not induce the typical hemianopic line bisection error (Schuett, Kentridge, Zihl, & Heywood, 2009) (but see diverging results in another recent study Mitra, Abegg, Viswanathan, & Barton, 2010). Together, both observations render a purely oculomotor explanation of the shift of the VSSA in our study unlikely.

4.1. (Ec)centric fixation

Similarly, significant eccentric fixation can be ruled out as an explanation for the spatial bias in the VSSA, as the horizontal and vertical positions of the blind spot were normal in all tested subjects and did not differ between both groups. This also rules out a possible *cyclorotation* of the eyes into the blind quadrant as a hypothetical explanation of the oblique shift of the VSSA into this quadrant, as in this case the centre of the blind spots should significantly deviate up or downwards from the normal position typically found slightly (0.5–3°) below the horizontal axis (Bixenman & von Noorden, 1982; Gradle & Meyer, 1929) This however, was not the case in our study (see Fig. 2). As a caveat, it should be mentioned that although blind spot mapping provides a rather precise measure of (ec)centric fixation *during* the perimetric mapping procedure, subtle shifts of fixation might go undetected with this method. Moreover, we cannot exclude the possibility that although *static* eye position was normal in all patients with quadrantanopia, *dynamic* eye position (i.e. during ocular scanning or visual straight ahead judgments) may differ in quadranopic patients from healthy control subjects. This question might be addressed in subsequent studies using eye-tracking-devices.

4.2. Multiple spatial misrepresentations in quadrantic field defects

The horizontal errors observed both in line bisection and in the VSSA were significantly correlated with each other, although not completely coincident, especially not in patients with rightsided HQ, who showed normal line bisection performance despite a contralesional shift of their VSSA. In contrast, horizontal line bisection and the vertical shift of the VSSA showed no correlation. This suggests relative independence of both types of spatial errors and is corroborated by the lack of any correlation between horizontal and vertical errors in the VSSA, both in the patients and control subjects. Hence, the vertical spatial error reported here for the VSSA seems to represent an additional, independent spatial bias apart from the horizontal errors previously reported for line bisection in HQ (Schuett et al., in press; Zihl et al., 2009) and the VSSA in hemianopia (Ferber & Karnath, 1999). Apparently, both spatial biases are combined into a new, hithertho unknown oblique spatial shift of the VSSA into the blind field in HQ. This shift is directed contralesionally in non-neglecting patients with HQ while it is directed ipsilesionally in patients with visual neglect (Schindler & Kerkhoff, 2004). The present study thus shows that apart from the horizontal bias in line bisection present in many (Schuett et al., in press) but not *all* patients with quadranopia (cf Machner et al., 2009a) such patients show a hitherto unknown oblique bias in subjective visual body orientation towards their blind quadrant.

In summary, non-neglecting patients with HQ show *multiple* spatial misrepresentations: (a) the well-known horizontal line bisection error (Schuett et al., in press; Zihl et al., 2009) which was present in 8/9 of our patients with left HQ, but only in 1/7 of those with right HQ, (b) the oblique shift of the VSSA described here for the first time, and (c) the retinotopic-specific spatial misrepresentation of visual distances along different meridians in the visual field (Doricchi et al., 2003).

The significant difference in horizontal line bisection in our patients with left vs. right quadranopia deserves some explanation. As visual field sparing on the horizontal meridian on the blind side did not differ significantly in both groups and was not correlated to the horizontal line bisection error, it is unlikely that the degree of intact field plays a significant role. Rather, it appears that patients with right hemisphere lesions and subsequently left quadranopia more often show a significant shift in line bisection, possibly because of the relative dominance of the right cerebral hemisphere in visuospatial judgments. Indirectly, this suggests that extrastriate cortical areas in the right cerebral hemisphere are more involved in visuospatial coding than those in the left cerebral hemisphere.

The manifold spatial deficits mentioned above probably cause multiple deficits in daily life, including those reported here in walking downstairs in patients with lower HQ. Our findings are compatible with the hypothesis that those extrastriate areas typically lesioned in patients with isolated HQ without neglect contribute to the visual coding of subjective visual body orientation in space, both in the horizontal and the vertical dimension. As patients with lower and upper HQ (respectively dorsal and ventral lesions of the postgeniculate pathway) showed this spatial error both pathways seem to be involved in this coding. However, the contribution of the more "dorsally" located postchiasmatic pathway seems to be more prominent as patients with lower HQ – subsequent to parietal lesions in all cases (Table 1) – showed the largest vertical errors. The downward shift of the VSSA in normal subjects may reflect an ecological adaptation that biases spatial attention and orientation towards the ground on which we move (Previc, 1990).

4.3. Conclusions

Non-neglecting patients with quadrantic field defects show a typical, hitherto unknown oblique spatial shift of their VSSA into the blind quadrants which is neither due to eccentric fixation nor rotation of the eyes, nor impaired scanning in the scotoma, nor neglect. It rather reflects impaired visuospatial coding of subjective visual body orientation due to the postchiasmatic lesion.

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