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Diurnal Variation of Visual Field Size in Patients with Postretinal Lesions

J. Zihl, E. Pöppel and D. von Cramon

Max-Planck-Institut für Psychiatrie, Laboratory for Neuropsychology, Kraepelinstr. 10, D – 8000 München 40, Federal Republic of Germany

Summary. Perimetry at various times of day in patients with large visual field defects due to postretinal lesions showed significant variations of visual field size. The largest visual fields were observed at noon, the smallest in the evening. Such systematic variations were observed only in patients who showed a gradual increase of increment threshold between the intact parts of the visual field and the scotoma. In two patients who showed an abrupt transition between intact and blind areas of the visual field, no obvious diurnal variation was observed. It is suggested that an endogenous modulation of neuronal sensitivity coupled to a hypothetical circadian oscillator is the basis of the diurnal variation.

Key words: Vision – Perimetry – Circadian variation – Brightness perception – Lesion

Lesions of the central visual pathways and their cortical target area are known to result in visual field defects (e.g., Teuber et al., 1960). Clinical observations on spontaneous recovery of function and recent experimental results on "residual vision" (Pöppel et al., 1973) or "blindsight" (Weiskrantz et al., 1974) within visual field defects indicate that functional loss after central lesions is often incomplete. Short-term changes in the borders of a scotoma resulting from a vascular lesion are frequently observed during perimetry, and are usually ascribed to "fatigue". It occurred to us to test whether there is a systematic variation of visual field size as a function of time of day, because for many psychological and physiological functions a diurnal rhythm has been shown (e.g., Aschoff, 1965; Pöppel, 1968; Pöppel and Giedke, 1970; Hockey and Colquhoun, 1972). We have found a significant diurnal variation of visual field size, but this variation depends on the slope of the increment thresholds between intact areas of the visual field and scotoma; only in the case of a gradual transition between these two areas can such a diurnal variation be demonstrated.

The visual fields were measured using the Tübingen perimeter (Sloan, 1971; Aulhorn and Harms, 1972). The patients fixated a red spot of light with 30 min visual angle at a distance of 33 cm. Head position was held stable by a chin rest and eye position was controlled by a telescope. The target (116 min visual angle; luminance: 100 asb) was projected onto a homogeneous background with a luminance of 10 asb. The patient had to push a button whenever he detected the target. Visual fields were measured four times (8 a.m., noon; 4 and 7 p.m.) on two different days. The two eyes were tested separately. During the test procedure the target was moved with a constant velocity of about 2 deg/sec from the periphery towards the center of the visual field. The border of the visual field was determined for twenty-four meridians; the sequence of measurements along the different meridians was randomized.

In addition monocular increment thresholds were determined along the horizontal meridian. Target luminance was chosen well above threshold and was then decreased in steps of 0.1 log units until the patient indicated that he no longer could see the target. In these measurements, targets had a diameter of 69′ and were presented for 500 msec. In addition visual acuity was determined for both eyes along the horizontal meridian. The task of the patient was to indicate whether he saw a circular or diamond-shaped target; luminance of these targets was 100 asb and they were presented for 500 msec; target sequence was randomized. As criterion for threshold, errorless performance was chosen. All measurements were performed on five patients with postretinal lesions (see Table 1).

Table 1. Age, clinical diagnosis and visual field defect of patients tested

Patient	Age	Diagnosis	Visual field defect
H. L.	49	unilateral occipital lobe necrosis	left homonymous hemianopsia
E. K.	42	unilateral occipital lobe necrosis	right homonymous hemianopsia
N. W.	51	bilateral occipital lobe necrosis	concentrically constricted reduced visual fields in both eyes
F. B.	17	craniocerebral trauma	right homonymous hemianopsia
U. C.	34	Sinus thrombosis	right homonymous hemianopsia

Visual fields, increment thresholds and visual acuity are shown in Figure 1 for the right eye of two patients (E.K.; F.B.) whose fields were measured at noon. Although the visual field size is similar for the two patients, the slopes for increment threshold and visual acuity measured along the horizontal meridian are quite different. The slope of the increment thresholds for the transition zone in the visual field of F.B. indicates a very sharp border between intact and blind region, whereas the slope for the increment thresholds in patient E.K. indicate a larger transition zone between the intact and blind regions.

The results obtained for the diurnal variation of visual field size show an increase in field size (corresponding to a decrease in the size of the scotoma) at

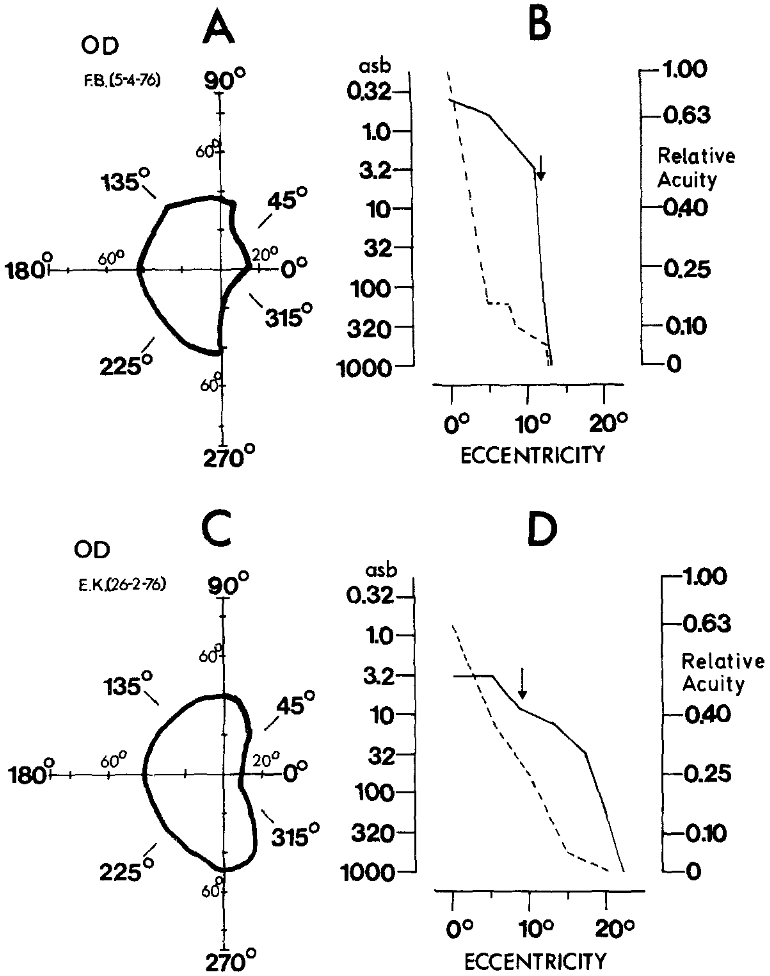

Fig. 1A–D. Visual field (**A**, **C**), increment threshold and visual acuity (**B**, **D**) of the right eye of two patients (F.B., cf. Fig. 4; E.K., cf. Fig. 3) with postretinal lesions. Increment threshold (continuous line) and visual acuity (errorless performance; interrupted line) were measured along the 0°-meridian in steps of 2° between the visual axis and the border of the visual field. The arrow indicates the border of the visual field measured by dynamic perimetry using a target with 69′ diameter

noon. This is true, however, only for those patients who show shallow slopes for increment thresholds between blind and intact regions in the visual field. An example of this relationship between diurnal variation of the visual field and the slope of increment thresholds is given in Figure 2; the visual fields of one patient (N.W.) are shown for two times of day (noon and 7 p.m.). The increment thresholds along the horizontal meridian indicate a gradual transition between the intact visual field and the scotoma. Such an increase in visual field size at noon followed by a decrease at evening was observed for three patients

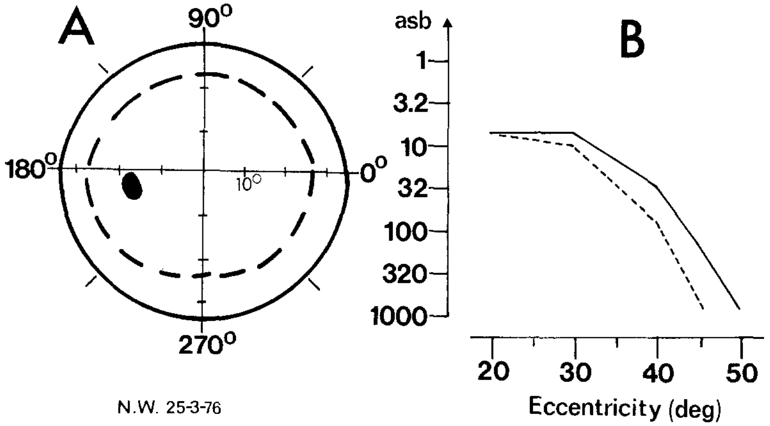

Fig. 2. **A** Visual fields of the left eye in a patient (N. W., cf. Fig. 3) with a postretinal lesion. The measurements were taken at two times of day (continuous line: noon; interrupted line: 7 p.m.). **B** Increment threshold measured at noon and 7 p.m. along the 0° meridian. Note the diurnal variability in A and the shallow slopes of increment threshold as well as the variation in increment threshold in B

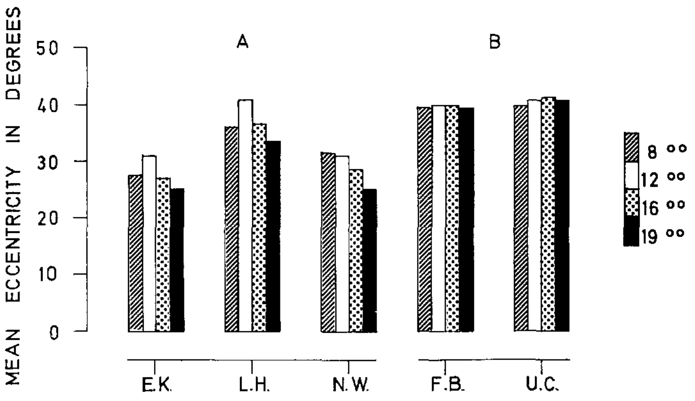

Fig. 3. **A** Variation in visual field size for the two eyes combined between 8 a.m. and 7 p.m. in 3 patients with postretinal lesions. Note that the visual fields are largest at noon, and smallest at 7 p.m. **B** Variation in visual field size for the two eyes combined in two patients with postretinal lesions. The slope of increment threshold at the border of the visual field was considerably steeper in these patients (cf. Fig. 1B) than in the other 3 patients (Fig. 3A, cf. Fig. 1D and Fig. 2B). Note the small degree of diurnal variability in these patients

(H.L., E.K., and N.W.). The variation of visual field size between 8 a.m. and 7 p.m. (mean eccentricity in degrees) is shown in Figure 3A. The data obtained from the three patients with such a gradual transition were analysed by the Friedman two-way analysis of variance (Siegel, 1956), and a significant result ($p < 0.05$) was obtained. In two patients who showed an abrupt transition between the two areas of the visual field, a diurnal variation could not be seen (e.g., F.B., Fig. 1). The results shown in Figure 3B for two patients (F.B.; U.C.) indicate rather stable visual fields throughout the day.

The diurnal variation in visual field size observed in certain kinds of visual field defects may suggest that neuronal sensitivity can be modulated. It might be argued that those neurones along the visual pathway that represent the transition zone between intact and blind regions of the visual field remain with their response sometimes below a threshold that normally has to be reached in order to lead to sensation. At noon the functional level of these neurones is highest, leading to an increase in visual field size. It is an open question which factors might influence this hypothetical variation of neuronal sensitivity. Some studies on circadian oscillation of brain temperature and on oxygen uptake (e.g., von St. Paul and Aschoff, 1968; Aschoff and Pohl, 1970) may suggest metabolic factors; diurnal fluctuations in blood pressure also may play a role (e.g., Klein et al., 1968). On the other hand, a modulation dependent on reticular activation might be envisaged. It has been shown (Singer, 1973; Singer et al., 1976) that reticular activation leads to facilitory effects in geniculate and striatal neurones; if there is a spontaneous diurnal variation of reticular activation, a corresponding variation of neuronal sensitivity at the cortical level which might underlie the variation in visual field size could be assumed.

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