Multiple Sclerosis

Luminance Threshold and Measurements of Temporal Characteristics of Vision

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• **Luminance threshold, perceptual latency, double-flash resolution, and critical flicker frequency were examined in patients with multiple sclerosis (MS) and in normal control subjects. The intensities of the stimuli used to test the temporal properties of vision were equalized with respect to individual luminance thresholds. In eight patients with MS, all the properties tested showed abnormality, double-flash resolution being most commonly affected. Retinal sites were not, however, uniformly abnormal according to these measures. We conclude that abnormal temporal properties of vision in patients with MS are not a simple functional consequence of altered luminance thresholds.**

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Damage to the visual system in patients with multiple sclerosis (MS) has been assessed by a number of tests that measure different aspects of visual function. Among these tests are measures of the temporal characteristics of vision, for example, perceptual latency, double-flash resolution, and critical flicker frequency (CFF), all of which have shown abnormalities in patients with MS.[1-5] Each of these measures is dependent on the intensity of the light stimulus used[6-9] and, indirectly, on a fundamental property of vision, namely, luminance threshold. This may also be abnormal in patients with MS, being either increased[10] or excessively variable.[11] It is therefore possible that if a stimulus of fixed intensity is used to measure a temporal property of vision, the recorded abnormality may be due to an abnormal luminance threshold and not to the temporal property under investigation. The purpose of the present study is to determine whether these abnormalities of temporal vision persist when variations in luminance threshold are taken into consideration.

SUBJECTS AND METHODS

Subjects

Fifteen patients with MS or optic neuritis were originally chosen for this study. Seven were found to have excessively variable luminance thresholds.[11] Because a consistent luminance threshold is needed to set the flash intensity when measuring temporal properties of vision, these patients could not complete the study. Clinical details of the eight remaining patients are given in Table 1. The disease was classified according to the criteria of Rose and others.[12] Optic atrophy was documented only if there was agreement between two independent observers; pupillary defects were sought with a swinging flashlight and visual fields were plotted on a tangent screen at 2 m.[13] The field defects found did not involve the central 10° of vision.

Ten healthy subjects acted as controls. They were members of hospital staff and showed a similar distribution of age, sex, and refractive error to the patients. All were unaware of the purpose of the experiment; informed consent of all subjects was obtained after the nature of the procedure had been fully explained.

Apparatus and Procedure

Subjects sat in a chair with a firm headrest and viewed a circular white screen 0.6 m in diameter at a distance of 1.6 m through an eyepiece. Spectacles were worn if appropriate, and the eye not being tested was lightly occluded. An artificial pupil

Table 1.—Clinical Details of Patients

Patient No./ Age, yr/Sex	Clinical Diagnosis*	Details of Eye Tested				
		History of Visual Disturbance	Visual Acuity (Snellen)	Pupillary Defect	Optic Atrophy	Field Defect
1/27/F	Definite MS	+	6/5	–	+	+
2/36/M	Definite MS	+	6/6	–	+	–
3/27/F	Definite MS	–	6/9	–	–	+
4/42/M	Definite MS	–	6/5	–	–	+
5/30/M	Definite MS	+	6/9	+	+	+
6/32/M	Definite MS	+	6/9	–	+	+
7/50/F	Recurrent ON	+	6/6	+	–	+
8/47/F	Definite MS	+	6/6	+	+	+

*MS indicates multiple sclerosis; ON, optic neuritis.

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Table 2.—Mean ± SD From Ten Control Subjects

	Fovea	2.5° Eccentricity	Variation Between Quadrants
Threshold, log μcandela	1.57 ± 0.25	1.96 ± 0.28	0.17 ± 0.08
Latency, ms	. . .	6.3 ± 13.0	22.5 ± 9.2
Double-flash resolution, ms	51.0 ± 3.9	65.8 ± 15.5	11.8 ± 6.8
Critical flicker frequency, Hz	28.1 ± 2.4	30.3 ± 4.3	2.9 ± 1.4

Table 3.—Significance of Results for Patients

	Field Site				
Factor Tested*	Fovea	Inferior Temporal	Superior Temporal	Superior Nasal	Inferior Nasal
Case 1					
T	NS	NS	NS	.01	.01
L	. . .	NS	NS	.01	.01
D	.01	NS	.01	.01	.01
F	NS	NS	NS	.01	.01
Case 2					
T	NS	NS	NS	NS	NS
L	. . .	.01	NS	NS	.01
D	NS	NS	NS	NS	NS
F	NS	NS	NS	NS	NS
Case 3					
T	NS	NS	NS	NS	NS
L	. . .	NS	NS	NS	NS
D	.01	.01	.01	.01	.01
F	NS	NS	NS	NS	NS
Case 4					
T	NS	NS	NS	NS	NS
L	. . .	NS	NS	.01	.01
D	.01	NS	NS	.01	.01
F	NS	NS	NS	NS	NS
Case 5					
T	NS	NS	NS	.01	.01
L	. . .	NS	.01	.01	.01
D	.01	.01	.01	.01	.01
F	NS	NS	NS	NS	NS
Case 6					
T	NS	NS	NS	NS	NS
L	. . .	NS	NS	NS	NS
D	NS	NS	NS	NS	NS
F	NS	NS	NS	NS	NS
Case 7					
T	NS	NS	NS	NS	.01
L	. . .	NS	NS	NS	NS
D	NS	NS	NS	NS	NS
F	NS	NS	NS	NS	NS
Case 8					
T	.01	.01	.01	.01	.01
L	. . .	NS	NS	NS	NS
D	NS	NS	NS	NS	NS
F	.01	NS	NS	NS	NS

*T indicates threshold; L, latency; D, double flash; F, critical flicker frequency.

was not used. The screen was uniformly illuminated by four incandescent lamps powered by a stabilized dc supply. Screen luminance was 2.0 log candelas/sq m.

Stimuli were provided by red light-emitting diodes (LEDs) of peak-emission wavelength (630 nm), which were controlled by suitable electronics. Each LED subtended 11′ of arc at the eye. Subjects fixated one of these LEDs placed at the center of the screen. A second LED was placed at 2.5° eccentricity. (For these stimulus conditions, there was no significant involvement of rod photoreceptors in the detection of the LED flashes.) Stimuli could be presented in three different ways: a single flash of 20 ms duration, a pair of 20-ms flashes presented to the same or different retinal sites, and a train of flashes, giving square-wave flicker with equal light and dark intervals. The flash intensity, the onset asynchrony of the pair of flashes, and the flicker of frequency could each be controlled by the examiner.

The characteristics of five retinal sites were examined in one eye of each subject. These sites were the fovea and four peripheral locations of 2.5° eccentricity and 45° orientation to the horizontal meridian in each quadrant. Each subject was tested in two sessions of about an hour each. In the first session, luminance threshold and then perceptual latency were measured; in the second session, luminance threshold and then double-flash resolution and CFF were measured. Fixation was not monitored directly, but all the patients had identified the blind spot consistently on visual-field testing and none had nystagmus. The individual measurements were made using a method of limits,[14] as follows.

Luminance Threshold.—The intensity of the LED flash was systematically varied in steps of 0.1 log units, and subjects were required to indicate on each flash presentation whether or not the flash was visible. The examiner controlled the intensity and timing of the presentation of the flash. Luminance threshold (increment threshold) was taken as the mean from two descending and ascending series. Threshold was thus determined first for the central site, then for each peripheral site, the subject fixating the central LED throughout.

Luminance threshold was classed as abnormally variable if the difference between a corresponding descending and ascending series was 0.5 log units or more.[11]

Perceptual Latency.—The latencies at the peripheral sites were determined with respect to the fovea of the same eye. The intensities of the LED flashes were individually set 1.15 log units above luminance threshold by appropriate manipulation of neutral density filters. The flashes were then presented asynchronously with the foveal flash obviously first. The subject, fixating the central LED throughout, was asked to say whether the "center" or "outside" light came on first and to avoid making any other response. The presentation was repeated if necessary. The onset asynchrony of the flashes was decreased by 20-ms intervals until the outside flash appeared to come on first on two consecutive presentations. The perceptual latency was taken as the mean from two such descending and similar ascending series. The sites were tested in the same order as for the threshold measurements.

Double-Flash Resolution—The intensity of the LED flash was set 1.15 log units above luminance threshold and an obviously resolvable pair of flashes was presented to the subject, who was asked to say whether he saw one flash or two. The onset asynchrony of the pair of flashes was decreased by 10-ms increments until they were perceived as a single flash on two consecutive presentations. Double-flash resolution was taken as the mean from two descending and ascending series. This procedure was followed for each site, central or peripheral, with the subject fixating the central LED throughout.

CFF.—The intensity of the LED flash was again set 1.15 log units above lumi-

nance threshold and a 2-s burst of obviously flickering light was presented to the subject, who was asked to say whether the light was "flickering" or "steady." The frequency was increased by increments of 2 Hz until the light was perceived as "steady" on two consecutive presentations. The CFF was taken as the mean from two ascending and descending series. This procedure was followed for all five sites, the subject again maintaining central fixation.

RESULTS

From the results in the ten control subjects, means and SDs were calculated for the following 11 variables: foveal luminance threshold, double-flash resolution, and CFF; peripheral luminance threshold, perceptual latency, double-flash resolution, and CFF; interquadrant variation in peripheral luminance threshold, perceptual latency, double-flash resolution, and CFF (Table 2). Interquadrant variation for each eye was expressed as the difference between the lowest and highest values for the four peripheral sites. Similar results are obtained when the SD of the values obtained at the four peripheral sites is used. The normal range for each variable was taken to include 99% of the corresponding normal distribution.

On the basis of these normal ranges, the measured value of each variable in the patients' eyes was classified as normal or abnormal. At the peripheral sites, values were also classified as abnormal if they differed from the corresponding value at another site in the same eye by more than the upper limit of normal interquadrant variation.

Results from the eight patients who completed the study are set out in Table 3. Of the 32 peripheral sites, 38% were normal for all functions tested. Double-flash resolution was abnormal at 41% of peripheral sites, luminance threshold at 28%, perceptual latency at 28%, and CFF at 6%. Of the eight foveal sites, 50% showed abnormal double-flash resolution; luminance threshold and CFF were each abnormal at one site.

COMMENT

The results show that abnormal temporal properties of vision can be demonstrated in patients with MS when the intensity of the light stimulus used is adjusted to compensate for individual differences in luminance threshold. The abnormalities of these properties reported previously do not therefore necessarily reflect underlying luminance threshold abnormality. Significantly, almost half of the patients selected initially for the present study were unable to complete the study because of excessively variable luminance thresholds. This phenomenon is more common than is generally realized in patients with MS and is particularly marked at the high background luminance level that we used.[11]

Double-flash resolution was the measure most often affected, values being abnormal at 13 of the 32 peripheral sites; CFF was the least often affected, values being abnormal at only two peripheral sites. This relative insensitivity of CFF may be related to the small size of stimulus (11′ of arc angular subtense) used in our measurements. It is known that CFF is dependent on many parameters of which the visual extent of the stimulus is particularly critical.[9] Authors who have reported greater abnormalities of CFF in patients with MS have used larger stimuli: Titcombe and Willison[4] used a 2.5° stimulus, and Daley et al[5] used a combined stimulus of 0.75° and 6°.

Two further points should be noted. First, although 63% of the chosen peripheral sites were abnormal, in one patient (case 6) tests were normal at all five sites despite a documented episode of optic neuritis, optic atrophy, and an arcuate scotoma on visual-field examination; normal function can thus apparently be maintained through a region in which there is almost certainly demyelination. Second, it is apparent that abnormalities of luminance threshold, perceptual latency, and double-flash resolution do not necessarily coincide at individual sites. This result is consistent with the findings by Galvin et al,[15] indicating that abnormalities in double-flash resolution and perceptual latency did not show the same retinal distribution; however, in the present study, one patient (case 1) did show abnormalities in all four measures at two distinct sites.

With regard to the possible pathophysiologic mechanisms underlying these phenomena, demyelination is known to block conduction in some fibers, either completely or intermittently, and to reduce conduction velocity in others.[16-18] The relative contribution of each of these factors to abnormalities in the various characteristics of vision measured here will clearly also depend on the local severity and extent of the demyelination. In principle, any permutation of abnormality in luminance threshold and temporal functions could thus arise at a given retinal site. In particular, as we have found, abnormalities in temporal properties of vision due to demyelination need not be a simple consequence of altered luminance thresholds.

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