Flicker Perimetry Resists Retinal Image Degradation

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The influence of refractive defocus and artificial media opacities on perimetric thresholds in automated light-sense and flicker perimetry was investigated in 20 eyes of 20 normal subjects. Thresholds were determined at 13 locations in the central visual field up to 25°. Refractive defocus was induced by blurring with glasses of +1, +2, +3, +6 and +9 diopters spherical. Three diffusers were used as artificial media opacities, causing a mean reduction of visual acuity to 0.46, 0.08, and 0.02. Blurring of the retinal image by a small defocus or by slight artificial media opacities causes a measurable reduction of light-difference sensitivity. Mean sensitivity (MS) and defocus are related logarithmically (log(MS)/defocus, r = -0.9297; P < 0.0001). The correlation between MS and the luminance factor 15, characterizing the artificial media opacities, is linear (MS/15, r = -0.9736; P < 0.0001). Flicker fusion frequency resists retinal image degradation much better. Mean flicker frequency (MF) and defocus are related logarithmically (log(MF)/defocus, r = -0.4960; P < 0.0001). The correlation between mean flicker frequency (MF) and the luminance factor 15 is nonlinear (MF/152, r = 0.8693; P < 0.0001). The results of the present study show that perimetric methods that use temporal threshold criteria, such as flicker fusion frequency, should be more suitable than methods that use static criteria for detecting neuronal damage in the presence of factors that disturb retinal image quality. Invest Ophthalmol Vis Sci 33:3539-3542, 1992.

Light-sense perimetry that measures the distribution of light-difference sensitivity in the visual field is affected by various factors that disturb the retinal image quality, such as media opacities (opacifications of cornea, lens and vitreous, especially cataract)1-3 or refractive defocus (not corrected or noncorrectable refractive errors).4 These are encountered frequently in clinical work. In recent times, perimetric techniques were developed to test temporal threshold criteria, such as flicker fusion frequency in flicker perimetry5,6 and temporal modulation sensitivity at 5 cycles per second in multi-flash campimetry.7 Interest is growing in these types of perimetric procedures because clinical and experimental data suggest that temporal transfer is affected early and selectively by glaucomatous damage.8 In addition, flicker fusion frequency, as measured by flicker perimetry, shows a high correlation with retinal nerve fiber layer loss in glaucomatous eyes.9

The goal of the present study was to investigate the influence of retinal image degradation induced by artificial media opacities and refractive defocus on perimetric thresholds in light-sense and flicker perimetry.

Materials and Methods

Materials

Twenty eyes of 20 normal subjects were examined by light-sense and flicker perimetry using different degrees of refractive defocus and artificial media opacities. The inclusion criteria were as follows. Subjects were required to have visual acuity ≥1.0 (20/20) without correction or corrected with a contact lens (<±4 diopters spherical), no relevant ocular pathology of the anterior segment (slitlamp) or fundus (indirect ophthalmoscopy in mydriasis), no systemic disease, and be under no psychotropic medication. The mean age of our study population was 26.7 yr (median 26.5 yr, minimum 23 yr, maximum 32 yr). Informed consent was obtained from all subjects.

Methods

Light-sense perimetry was performed with the Humphrey Field Analyzer (HFA; Humphrey Instruments, Inc., San Leandro, CA). For the present study, a special program was designed to test 13 points in the central visual field up to 25° (fovea plus 12 locations on the oblique meridians under 5°, 15°, and 25°) us-
ing a twofold bracketing procedure. Flicker perimetry, testing flicker fusion frequency, was performed with the system described by Lachenmayr and co-workers using the same test point pattern used with the HFA. For each individual visual field, mean sensitivity (MS; dB) and mean flicker frequency (MF; cps) were calculated as the average of all 13 tested points. Refractive defocus was induced by blurring with glasses of +1, +2, +3, +6 and +9 dpt spherical, added to the appropriate distance correction of +3 dpt spherical. Artificial media opacities were produced by covering glasses with homogeneous layers of ointment that had different densities, corresponding to a mean reduction of visual acuity to 0.46, 0.08, and 0.02. The luminance factor 115 (see appendix) for the three diffusers was 0.0135, 0.0303, and 0.0446 cd/m²·lux. In addition, a baseline value without opacity or refractive defocus was determined.

**Results**

MS decreased markedly with increasing refractive defocus (Fig. 1) or with increasing luminance factor 115 (Fig. 2). There is a logarithmic relationship between MS and defocus (log[MS]/defocus, r = −0.9297; P < 0.0001). The correlation between MS and the luminance factor 115 is linear: (MS/l15, r = −0.9736; P < 0.0001). When mean visual acuity obtained through the artificial media opacities was used instead of l15, the correlation was strongly nonlinear (MS/log (acuity), r = 0.9628; P < 0.0001).

MF also decreased with increasing defocus and increasing luminance factor l15. The dropoff, however, occurred at much higher values of refractive defocus (Fig. 3) and with much denser artificial media opacities (Fig. 4). There was a logarithmic relationship between MF and defocus (log (MF)/defocus, r = −0.4960; P < 0.0001). The correlation between MF and the luminance factor l15 was nonlinear (MF/(l15)², r = −0.8693; P < 0.0001). The correlation between MF and mean visual acuity obtained through the artificial media opacities also is strongly nonlinear (MF²/log [acuity], r = 0.9136; P < 0.0001).

Marked qualitative and quantitative differences between light-sense and flicker perimetry are shown in

**Fig. 1.** Influence of refractive defocus on light-difference sensitivity in light-sense perimetry: Mean sensitivity (MS) as a function of defocus (log[MS]/defocus, r = −0.9297, P < 0.0001).

**Fig. 2.** Influence of artificial media opacities on light-difference sensitivity in light-sense perimetry: Mean sensitivity (MS) as a function of luminance factor l15 of the artificial media opacities (MS/l15, r = −0.9736, P < 0.0001).

**Fig. 3.** Influence of refractive defocus on flicker fusion frequency in flicker perimetry: Mean flicker fusion frequency (MF) as a function of defocus (log[MF]/defocus, r = −0.4960, P < 0.0001).
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![Image](http://iovs.arvojournals.org/pdfaccess.ashx?url=/data/journals/iovs/933384/)

**Fig. 4.** Influence of artificial media opacities on flicker fusion frequency in flicker perimetry: Mean flicker fusion frequency (MF) as a function of luminance factor $I_{15}$ of the artificial media opacities ($MF/(I_{15})^2$, $r = -0.8693$, $P < 0.0001$).

Figures 1–4. Blurring the retinal image by a defocus of 1 dpt caused a reduction in MS of approximately 3 dB (Fig. 1). The same amount of defocus did not create a noticeable reduction in MF (Fig. 3). Even a blur of 9 dpt caused only a slight reduction in MF of 5 cps. A similar relationship is valid for the artificial media opacities. Only very dense opacities caused a measurable reduction in MF (Fig. 4) as opposed to MS (Fig. 2).

**Discussion**

The results of the present study show that a temporal threshold criterion, such as flicker fusion frequency as measured in automated flicker perimetry, is rather independent of factors that create retinal image degradation. Even a strong refractive blur caused only a slight reduction of MF in the central visual field. Only very dense artificial media opacities that reduced visual acuity to less than 0.1 caused a noticeable reduction of MF. A possible explanation for this phenomenon could be that a flicker stimulus as used in the present study, with a symmetrical modulation of 100% around the mean luminance level, is less affected by a reduction of retinal image contrast than a stimulus as used in light-sense perimetry, which simply is added to the surround level. Some, but not all of this effect might be the result of the difference in target size used in the present study for light-sense and flicker perimetry (0.43° versus 1° diameter). Different target sizes were used because we wanted to compare perimetric techniques in the standard configuration as they are currently used for clinical purposes in our glaucoma service.

Light-sense perimetry, however, was strongly affected by refractive defocus or artificial media opacities. Introducing a defocus of +1 dpt reduced MS in the central visual field by approximately 3 dB. Increasing the amount of defocus from +1 dpt to +2 dpt caused a somewhat smaller reduction of MS, by approximately 1.7 dB. Increasing the defocus from +2 dpt to +3 dpt reduced MS by another 1.4 dB. Thus, we found that the relative influence of defocus decreased with increasing amount of blur. Weinreb and Perlman\(^4\) reported a somewhat smaller effect of defocus on MS—only 1.3 dB/dpt. Heuer et al\(^2\) also found a smaller influence of defocus on MS—1.4 dB for a defocus of +1 dpt spherical and 2.9 dB for a defocus of +2 dpt spherical. The studies of Weinreb and Perlman\(^4\) and Heuer et al\(^3\) were performed with Octopus peripherals that use a standard background luminance of 1.27 cd/m², whereas the HFA, as used in the present study, has a background luminance of 10 cd/m². This higher adaptation level may explain the more pronounced effect of refractive defocus in our study. This hypothesis is supported by the observation of Heuer et al,\(^3\) who found a greater influence of diffusers for the HFA compared to the Octopus 201. For their diffuser no. 4, which reduced visual acuity to a mean of 0.87 ± 0.18, the Octopus thresholds increased by an average of 6.6 dB. The Humphrey thresholds, however, increased by 8.1 dB.

Our observation that the results of flicker perimetry in the central visual field are fairly resistant to retinal image degradation agrees with the report by Tyler,\(^10\) who measured foveal flicker sensitivity in six eyes of six subjects with and without a refractive blur of +10 dpt spherical. Even with this large amount of blur, he could not find a statistically significant loss of foveal flicker sensitivity. Under clinical circumstances, disturbing factors, such as media opacities or refractive defocus, are encountered frequently and cause problems with interpreting visual field data. A generalized reduction of light-difference sensitivity as measured by light-sense perimetry may be the result of actual retinal damage, such as diffuse glaucomatous nerve-fiber loss, or disturbing factors that affect retinal image quality. Thus, perimetric methods that use temporal threshold criteria may—to a certain extent—result in the “bypassing” of disturbing factors, such as media opacities or uncorrected or noncorrectable refractive errors. The resistance of flicker perimetry to retinal image degradation is similar to the observation of Enoch et al\(^11\) and Williams et al,\(^12\) who used hyperacuity targets to assess macular function in the presence of artificial media opacities.
Appendix

The luminance factor $l_{15}$, used to quantitatively assess the artificial media opacities, is defined as follows.

$$l_{15}(\text{cd}/\text{m}^2/\text{lx}) = \frac{L_s(\text{cd}/\text{m}^2)}{E_0(\text{lx})}$$  \hspace{1cm} (1)

$l_{15}$ = luminance factor for an angle of 15° between the illuminating beam and the measuring beam. $L_s$ = luminance of scattered light under an angle of 15°. $E_0$ = illuminance of illuminating beam at the entrance plane of the scattering medium.

Photometrically, the luminance factor $l_{15}$ is determined by measuring the luminance of the light scattered by the artificial media opacity under an angle of 15° relative to the illuminating beam.

Key words: artificial media opacities, flicker perimetry, light-sense perimetry, refractive defocus, retinal image quality

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References