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Visual Acuity Measurement With a Second-Generation Scanning Laser Ophthalmoscope

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Individuals with longstanding macular scotomas use an idiosyncratic, non-foveal retinal area adjacent to the scotoma to fixate and to inspect detailed visual stimuli (1). It is not known whether this preferred retinal locus (PRL) "selected" by the patient is the retinal area of highest residual visual acuity or how acuity is modified in retinal areas surrounding the scotoma. Because this information could be useful in visual rehabilitation of patients with macular disease we have developed a technique for measuring acuity at specific retinal loci using the Scanning Laser Ophthalmoscope (SLO) (2).

The Generation-II SLO allows presentation of acuity targets with gap widths as small as 3 min arc (one pixel), a marked improvement over the 7 min arc minimum of the Generation-I machine. Nevertheless, the high-contrast 3 min arc target (equivalent to a 20/60 acuity) is often not small enough to allow acuity measurement at retinal loci close to the foveola. To circumvent this limitation, we measure acuity with low- as well as high-contrast targets since such measurements have proven useful in clinical vision assessment (3). Our low-contrast acuity measurements, reported here, reveal retinal acuity asymmetries in ocularly normal subjects.

Method

Unlike the Generation-I machine, the Generation-II SLO (Fig. 1) produces a true RS-170 laser-beam raster by scanning the beam horizontally at 15,750 Hz with an acoustooptic deflector (AOD). Convex mirrors (CM's) and off-axis parabolic mirrors (OAP's) form a beam expander that shapes the laser-beam to match the slit-shaped aperture of the AOD. A mirror-galvanometer (VMG) then scans the beam vertically at 60 Hz, forming the raster. After passing through lenses (L's) and a polarizer (P), the raster is brought to focus on the retina by an aspheric lens (AL). Light scattered from the retina is collected by lenses AL, L4, and L5 and imaged on the photocathode of a photomultiplier (PMT). Signals from the PMT are amplified and displayed on a video monitor synchronized to the laser-beam scan, thus showing an image of the retina.

Visual stimuli are produced in the laser-beam raster by a microcomputer with 512 X 512 pixel X 4 bit video graphics card that modulates laser beam intensity by means of an acoustooptic modulator (AOM). Stimuli can be moved automatically under program control or by manual control with a "mouse" connected to

the computer. Complex stimuli such as photographs of faces can be produced in the raster by means of a television camera and video frame memory. Retinal light levels are monitored by a radiometer; should retinal power density exceed a preset level, the laser beam is automatically blocked by a shutter.

To measure visual acuity at a particular retinal locus, the subject fixates a small dot in the raster. The experimenter views the video monitor and with the "mouse" positions a point at the retinal locus to be tested. The point is then removed and the computer presents a Snellen E acuity target at the same locus for 0.5 sec. Acuity is then measured using a standard four-alternative, forced-choice, staircase procedure.

We measured visual acuity along the 8 major meridians (horizontal, vertical, and two obliques) at 2, 6, and 10 deg of eccentricity. Three target constrasts were tested: 99% (high), 50% (medium), and 20% (low). The experimenter monitored the subject's retinal position on the video monitor and presented an acuity stimulus when fixation was adequate. Trials during which the subject lost fixation were deleted and another trial was run. All SLO images were videotaped and later inspected to check adequacy of target placement.

Results

Retinal size of the threshold acuity target was plotted on an SLO image of the subject's retina at the retinal location where it was measured. Figure 2 is such a plot for low-contrast targets. Each square in the figure shows the overall size of the threshold acuity target (five times the target gap width). The image of the retina has been electronically "rotated" so that it is equivalent to a projection of the retina onto the visual field. Anatomically, nasal retina is to the left (toward the optic disc) and inferior retina is at the top. The small dark dot in the center is the fixation target on the subject's foveola. Not surprisingly, Fig. 2 shows that low-contrast acuity decreases with increasing retinal eccentricity from the foveola (i.e., threshold target size increases). Somewhat unexpectedly, however, there appear to be marked meridional asymmetries: threshold acuity was poorer in the upper and right visual field. Similar variations were found with the medium contrast stimuli, but were not obvious with the high-contrast targets.

We graphed threshold acuity data for each target contrast and meridian and determined retinal iso-acuity profiles by linear interpolation between data points. Iso-acuity contours were then plotted on the appropriate retinal location on an SLO image of the subject's retina. Figure 3 shows the low-contrast iso-acuity map based on the data shown in Fig. 2. Numbers on each contour show the acuity in minutes of arc. Retinal asymmetries in low-contrast acuity are even more obvious in the iso-acuity plot: acuity falls off rapidly in the subject's upper-right visual field (superior-temporal retina). Relatively large retinal areas of constant acuity extend down and to the left from the subject's

foveola (black dot), indicating areas of better acuity nasal and superior to the fovea.

Discussion

Medium- and low-contrast SLO retinal iso-acuity contours exhibit compression of contours in the upper visual field (inferior retina) and spread along the horizontal meridian. Similarly shaped contours have been found by others measuring contrast sensitivity with sine-wave grating patches (4) and single sine-wave cycles (5). Our high-contrast acuity measurements do not reveal the marked retinal asymmetries seen with the medium- and low-contrast stimuli. Thus, low-contrast, spatially restricted stimuli may be useful in revealing retinal variations in spatial visual sensitivity.

Although we have begun to measure acuity at the PRL of patients with macular scotomas, we do not yet know the pattern of retinal iso-acuity contours outside the scotomas. If the patient's iso-acuity contours outside the scotoma are undistorted by the disease process and similar in form to those found with ocularly normal subjects, they may make most effective use of residual vision by using nasal-superior retinal regions.

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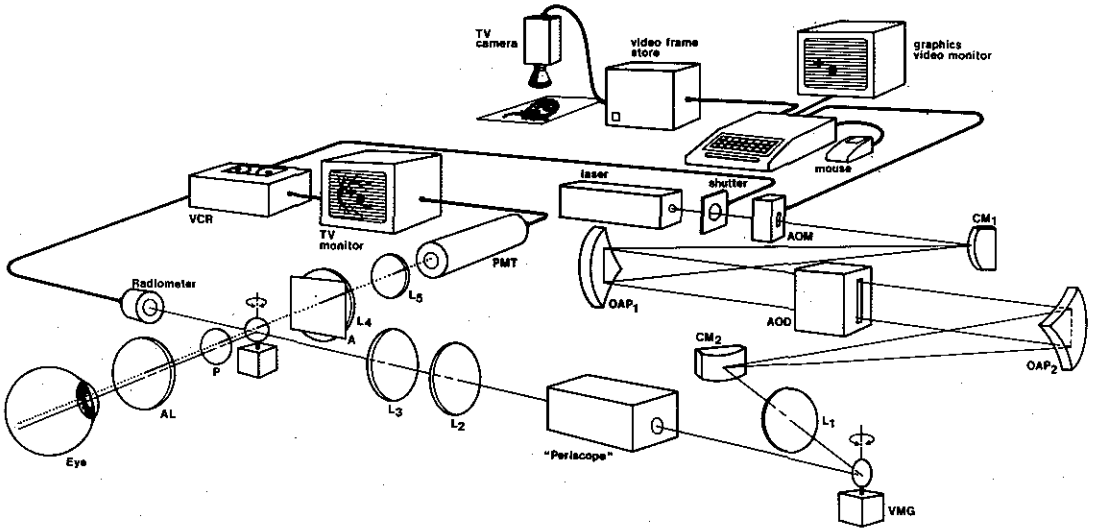

Figure 1

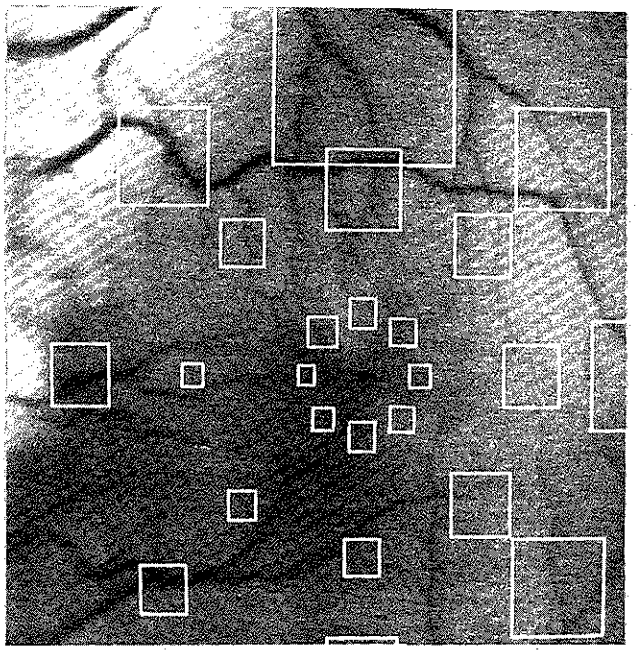

Figure 2

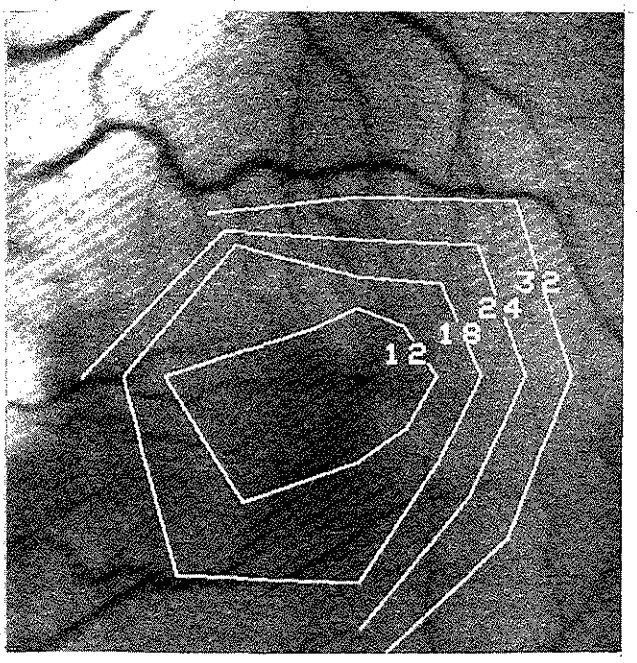

Figure 3