between red vessels and portions of the disc with greatest pallor.

Measurement variability is contributed by a number of sources, including camera positioning, camera temperature and ambient illumination. The red and green images are not recorded simultaneously; variations in image registration and fluctuations of the specular reflections from the ocular media and blood vessels may alter computed pallor densities. It is not yet known what effect aging changes of the ocular media will have on sequential pallor measurements. We expect the aging lens to shift the entire distribution toward smaller (less pale) pallor densities, but measures of distribution width may be less affected.

The present study demonstrates the feasibility of videographic methods to provide rapid, quantitative measurements of optic disc pallor. Work is underway to investigate the utility of this method in the early diagnosis of glaucoma.

Key words: optic disc pallor, computerized image analysis, glaucoma, videogrammetry, trimmed means

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Does Impaired Contrast Sensitivity Explain the Spatial Uncertainty of Amblyopes?

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We investigated the possibility that the spatial imprecision of amblyopic eyes can be accounted for by the relative insensitivity to contrast that has been documented for these eyes. Thresholds for the discrimination of spatial misalignment, a measure of spatial uncertainty, were determined for three amblyopes and one normal for targets ranging in contrast from detection threshold to 99%. We found that spatial uncertainty was greater in amblyopic eyes than non-amblyopic eyes for targets equally above contrast threshold, and when the targets were presented at threshold contrast to the nonamblyopic eyes and at 99% contrast to the amblyopic eyes. Our results fail to support the possibility that the spatial imprecision of amblyopic eyes can, in general, be attributed to reduced contrast sensitivity. Different neural abnormalities are presumed to limit amblyopes’ performance on different spatial tasks. Invest Ophthalmol Vis Sci 29:323–326, 1988

Imprecision in spatial directionalization tasks, that is, spatial uncertainty, is a characteristic of strabismic and, to a lesser degree, anisometropic amblyopia.1–3 One way in which this spatial imprecision is revealed and measured is as insensitivity to offset in Vernier-type alignment tasks. Also characteristic of strabismic and anisometropic amblyopic eyes is a decreased sensitivity to contrast at most spatial frequencies (eg, refs. 4, 5). Recently, Bradley and Freeman6 raised the possibility that the insensitivity to offset of the am-
Fig. 1. A measure of spatial uncertainty, line-displacement threshold, is plotted as a function of contrast for the amblyopic and preferred eyes of three amblyopes and one eye of a normal. The lowest contrast value plotted for each eye represents the approximate 60% detection threshold for the flashed target stimulus.

Materials and Methods. In the task, the subject monocularly fixates the 1.5° space between the vertically aligned apices of two equilateral triangles presented on an otherwise dark screen of a Commodore (Santa Clara, CA) PET 2000 microcomputer. Using a method of constant stimuli, a 0.5° vertical line is presented for 125 msec at various horizontal positions midway between the triangles. In a two-alternative forced-choice paradigm, the subject reports on each trial whether the target appeared rightward or leftward of the alignment indicated by the apices of the triangles (for more complete details of this task and an illustration of the stimulus display, see ref. 1). We find that the amblyopic eye shows a greater spatial uncertainty than the normal and preferred eyes, that the degree of uncertainty is related to the depth of amblyopia, and that the amblyopic eyes of strabismics typically show a greater uncertainty than those of anisometropes.

For the present investigation we collected data on three amblyopes (two with esotropia and anisometropia, one with anisometropia only) and one normal observer. Contrast (L_{max} - L_{min}/L_{max} + L_{min}) of the entire display varied over a wide range, from 99% to the contrast required for the 60% detection threshold for the flashed target. Contrast was manipulated by optically superimposing a veiling luminance produced by an approximately 1300 cd/m² source onto the computer screen (target and reference triangles at a constant 42 cd/m²) which itself was viewed through a neutral density filter acting as a beam splitter. The various contrast levels were produced by varying the value of the neutral density filter which in turn varied the effective luminance at the subject's eye. The data were analyzed using probit analysis. As a measure of spatial uncertainty we used line-displacement threshold, specifically, the change in target position required for a change in the probability of a "rightward" response from 50% to 84%. Voluntary informed consent was obtained from all observers prior to participation.

Results. The results are summarized in Figure 1, which shows line-displacement thresholds plotted as a function of contrast for each eye separately. The notion that differential contrast sensitivity accounts for the relative spatial uncertainty of the amblyopic eye can be evaluated by comparing the data of each amblyopic subject's two eyes when the stimuli are equally visible, namely, the threshold contrast condition. Clearly, under this condition of equal visibility, the amblyopic eye was less sensitive to line displace-
Fig. 2. Percent "rightward" responses for target stimulus positions relative to the veridical alignment (0) for the amblyopic eye at 99% contrast and for the preferred eye at detection threshold contrast.

Fig. 3. Comparison of the line-displacement thresholds–contrast functions for the stimuli presented foveally and at the eccentric fixation locus of a strabismic amblyopic eye. Note that the fovea is less spatially sensitive than the eccentric fixation locus (EF), an observation we have made before (ref. 1, p. 914).
In addition to spatial uncertainty, strabismic amblyopic eyes also typically exhibit spatial distortion—substantial constant errors of alignment (eg, ref. 2). We found no evidence that spatial distortion of the type and magnitude found in the amblyopic eyes of our subjects can be induced in their preferred eyes by reducing the contrast of the stimulus. For example, at 99% contrast strabismic J.V.'s amblyopic eye showed a sizeable constant error of 11.6 ± 1.5 (standard error) min arc leftward, but at threshold contrast his preferred eye showed virtually no constant error, 0.9 ± 0.6 min arc (Fig. 2).

Discussion. The proposal that imprecision of strabismic and anisometropic amblyopic eyes in spatial directionalization tasks can be accounted for by insensitivity to target contrast is not supported by our results. Contrast insensitivity has also been found to be unable to account for amblyopic eyes' impaired discrimination of spatial phase and, recently for anisometric amblyopic eyes, abnormally poor discrimination of shape. Thus, although decreased contrast sensitivity of amblyopic eyes may explain performance on certain tasks, the generality of this explanation is limited.

It is likely that multiple sensory deficits characterize most amblyopic eyes, and studies by us as well as others have been directed toward establishing what these deficits may be and how they vary according to etiology. In normal eyes, any one of several cues (local features, relative position, orientation, etc.) may determine the level of optimal performance in, for example, Vernier alignment tasks, depending upon the stimulus configuration and conditions. The different cues in a visual stimulus are presumably affected to greater and lesser degrees by the amblyopic eye's multiple deficits, so that on different tasks the limit placed on performance might be expected to result from different deficits. Thus, at present it is probably not appropriate to specify any amblyopic deficit as fundamental without also identifying the particular task at issue.

Key words: amblyopia, contrast, spatial uncertainty, anisometropia, strabismus

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