The effectiveness of a retinoscope beam as an accommodative stimulus

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Two experiments with adult subjects and one with infant subjects showed that the beam of a retinoscope, when viewed monocularly in a dark surround, does not stimulate accommodation. In this situation, the eye assumes an intermediate focus that is correlated with the individual's intermediate dark focus or resting state of accommodation. These results provide further evidence that near retinoscopy is a useful method of refraction which controls accommodation by minimizing effective stimulation. The technique is particularly valuable for refracting infants or young children who would otherwise require cycloplegia, and it may be an effective clinical method for the correction of night myopia and related anomalies in adults.

Key words: infant refraction, accommodation, near retinoscopy, resting focus, night myopia

In order to refract infants without the use of cycloplegic drugs, Mohindra1 has developed a technique referred to as near retinoscopy. This method takes advantage of the well-known tendency of young infants to fixate visually salient stimuli,² by creating a situation in which the light source of a retinoscope is the only visible stimulus. With this procedure, the infant is seated in the parent's lap, the room lights are extinguished, and retinoscopy is performed from a working distance of 50 cm. To help attract and hold the baby's attention, the retinoscopist produces a variety of interesting sound effects. In this situation, most infants will fixate the retinoscope steadily for several minutes, allowing time for the determination of both spherical and cylindrical refraction.

Accurate evaluation of refractive errors requires that accommodation be stable and known at the time of measurement. This essential control is typically achieved by one of three methods: (1) by providing a distant accommodative stimulus, such as an acuity chart; (2) by paralyzing the ciliary muscle with cycloplegic drugs; or (3) by providing only neutral or ineffective accommodative stimuli, as practiced with some infrared refractometers and with various research systems such as the stigmatoscope³ and the laser optometer.⁴

A distant accommodative stimulus represents the most naturalistic and probably the most effective method for controlling accommodation during refraction. However, a distant fixation target is of little value in the measurement of infants' or young children's refraction because controlling their attention is often difficult. Consequently, the use of cycloplegia has become the standard procedure in refracting young subjects. Although this method assures that accommodation will be stable during refraction, the possibility of adverse side effects precludes the use of cycloplegics for frequently repeated refraction.
of the same subject and for patients who might exhibit an allergic reaction to the drug. Moreover, the manifest cycloplegic refraction requires a ciliary "tonus adjustment" which cannot be estimated precisely, since its value depends on the amount of drug absorbed and on the patient's relative sensitivity to the drug. A noncycloplegic refraction technique for infants would therefore be quite useful both for routine clinical examinations and for studying age-related changes of refraction and accommodation during early life.

Near retinoscopy represents the first attempt to control the accommodation of infants by providing an ineffective or neutral accommodative stimulus during refraction. A crucial assumption of this technique is that the light source and the exit aperture of the retinoscope do not influence accommodation. In support of this assumption, Mohindra found that near retinoscopic refractions of adults are highly correlated with their subjective refractions. She has also shown that near retinoscopic refractions of children and infants are highly correlated with their cycloplegic refractions. These findings imply that when viewed in a dark surround, a retinoscope filament is not an effective accommodative stimulus. Otherwise, the patient's accommodation would change as the retinoscopist varied the vergence of the retinoscope beam, resulting in spurious measures that would be unrelated to the actual refractive error.

Numerous investigations have established that in darkness or in a bright empty field, the eye focuses for an intermediate distance which has been referred to as the dark focus or the intermediate resting state of accommodation. That is, most emmetropes and corrected ametropes exhibit accommodative "myopia" under reduced stimulus conditions. Consistent with these findings, Mohindra has determined that a tonus adjustment of +0.75 D must be added to the static refraction obtained by the near retinoscopic method. Thus near retinoscopic measures tend to indicate more myopia than subjective or cycloplegic refractions of the same individual, suggesting that accommodation shifts toward the intermediate resting focus during near retinoscopy. This hypothesis is consistent with the finding that a fixation point, viewed in a dark surround, is a neutral accommodative stimulus. In this situation, accommodation remains near the observer's characteristic resting state regardless of the target distance.

Three experiments were conducted to assess the influence of a retinoscope beam on accommodation. In the first experiment, near retinoscopic refractions were compared with the same adults' intermediate resting focus of accommodation as measured with a laser optometer. In the second experiment, the laser optometer was used to measure the accommodative responses of adults for a retinoscope that was viewed monocularly in the dark at distances ranging from 100 to 25 cm. In the third experiment, retinoscopy was used to refract infants in a dark room at working distances ranging from 100 to 25 cm.

Experiments I and II

Subjects. Twenty-four adults, from 19 to 30 years of age (mean 23.4 years), served as subjects. All exhibited far visual acuity of at least 20/30 with their normal optical correction, which was worn throughout the experiments. Five subjects participated only in the first experiment, 13 served only in the second experiment, and six served in both experiments.

Apparatus. Near retinoscopy was performed with a streak retinoscope fitted with a quartz-halogen bulb (Welsh-Allyn, 18100). Its light source was adjusted to maximum intensity and positioned as far as possible from the retinoscope head so that the vergence of the beam was —1.0 D. The laser optometer was similar to those described in several earlier reports. The beam of a low-output He-Ne laser was diverged and collimated and then reflected from the surface of a slowly rotating drum. This resulted in an elliptical, monochromatic (632.8 nm) speckle pattern which subtended 2.6 by 5.1° of visual angle in the horizontal and vertical dimensions, respectively. A beam splitter was used to superimpose this speckle pattern on the accommodative stimuli, which were viewed either directly (in the case of the retinoscope) or through a Maxwellian view.
Fig. 1. Scatter diagram comparing the refractive states of 22 eyes during near retinoscopy with those obtained in a dim, empty field, i.e., the resting focus of accommodation. Different symbols are used to represent the data of each subject. Refraction values are given as the spherical lens power required to correct the focus of the eyes to optical infinity. No tonus adjustment was applied to the near-retinoscopy refractions.

optical system (in the case of the letter matrix and the empty field). The Maxwellian view system was constructed as follows. Light from a quartz-halogen bulb was collimated and focused by a 4.5 D field lens at a 3.5 mm artificial pupil. Viewing through the artificial pupil, subjects saw a circular, monocular stimulus field that subtended 7.8° of visual angle in diameter. To assure that the outside edge of this field did not serve as an accommodative stimulus, it was blurred optically to produce a gradually diminishing luminance profile. A chin and forehead rest held the subject’s head in alignment with the optical system, and opaque screens shielded the apparatus from view. The intensity of the laser test pattern was adjusted with neutral filters so that the brightest speckles were just visible when superimposed on the stimulus field; its exposure duration was limited to 0.75 sec by a mechanical shutter.

Procedure. In the first experiment, near retinoscopic refractions of 11 subjects were taken in a dark room from a working distance of 50 cm. With one eye patched, the subject was asked to fixate the light source of the retinoscope, and retinoscopy was performed three times in succession with the use of a lens bar to find the spherical power required to obtain a neutral reflex in the vertical meridian. This measure was corrected for working distance (—2.0 D). However, unlike the usual clinical procedure, the near retinoscopic tonus adjustment (+0.75 D) was not applied to these measures. The average value of these measures therefore represented the subject’s actual refractive state during near retinoscopy. The eye’s refractive state while viewing a dim empty field was then measured with the laser optometer. This neutral stimulus condition was created by presenting the empty Maxwellian view stimulus field with luminance reduced by neutral filters to approximately 1 cd/m². Three successive measures were obtained by a bracketing technique in which the laser pattern was flashed intermittently, first at extreme near and far optical distances. The subject’s task was to report the apparent direction of speckle motion after each presentation. Over a series of presentations, the test pattern was adjusted until the plane of minimal speckle motion was found. This was usually accomplished in five to 10 flashes of the test pattern, taking 30 to 60 sec. After application of correction factors to compensate for the axial chromatic aberation of the eye and for the curvature of the reflecting surface, the average value of these measures was taken as the subject’s resting focus of accommodation.

In the second experiment, accommodative responses of 20 subjects were measured with the laser optometer while they monocularly fixated (1) the dim, empty field; (2) the retinoscope, in a dark surround at distances of 25, 50, 75, and 100 cm; and (3) a brightly illuminated matrix of Snellen E’s presented at optical distances of 4.0, 3.0, 2.0, 1.0, and 0.0 D. The filament of the retinoscope was always stationary and in the vertical orientation. In all other respects, the empty field and retinoscope conditions were similar to those used in experiment I. The 3 by 3 matrix of Snellen E’s was a high-quality photographic transparency positioned in the collimated beam of the Maxwellian view system. Its optical distance could be varied (with no concomitant change in size) by adjusting its distance from the field lens. Each letter subtended 1.28° of visual angle, with a line width of 15 min arc. Background luminance was approximately 1000 cd/m². For all subjects, the empty-field measures were taken twice at the beginning and twice at the end of each session. The retinoscope stimulus condition was presented first for half of the subjects, and the letter matrix condition was presented first for the other subjects. Accommodation was measured twice at each viewing distance for both of these stimuli, once in a series of…
increasing distances and once in a series of decreasing distances.

Nine additional subjects were tested in a control experiment which followed the same procedure as experiment II, except that the retinoscope was presented at four luminous intensities. Neutral-density filters were used to vary illumination from maximum to 0.1, 0.01, and 0.0001 of the maximum intensity. To minimize the effect of afterimages, these intensities were always tested in increasing order.

Results and discussion. Fig. 1 presents a scatter diagram illustrating the results of the first experiment. Each point represents the data from a single eye. Its ordinate gives near retinoscopic refraction of the eye, and its abscissa gives the empty-field refraction, i.e., the resting focus of accommodation. These measures were highly correlated (Pearson's $r = 0.86$, $p < 0.0001$), suggesting that accommodation shifted toward the subjects' intermediate resting focus during near retinoscopy. However, as shown by the solid regression line, the refractive states obtained with the empty field and near retinoscopy were not equivalent. Identical accommodation under both conditions would have produced a regression line with a slope of 1.0. The obtained slope was only 0.64, indicating that the subjects focused nearer when viewing the empty field (mean 1.50 D) than when viewing the retinoscope (mean 0.70 D).

These mean values are remarkably similar to data from earlier research. Leibowitz and Owens\textsuperscript{15} found the average dark focus of 220 college students to be 1.52 D. The dark focus is thought to represent the physiologic resting state of accommodation, which would also be obtained when viewing a bright empty field.\textsuperscript{10, 11} Thus the present sample of subjects exhibited an average resting focus that was nearly identical to that of the larger group tested by Leibowitz and Owens. Furthermore, based on comparisons of near retinoscopy and subjective refractions, Mohindra\textsuperscript{2} concluded that a tonus adjustment of 0.75 D should be added to near retinoscopic measures to obtain the appropriate prescription for distance. This correction factor would effectively compensate for the average accommodation shown be that of the present subjects during near retinoscopy.

The discrepancy between the near retinoscopy and empty-field refractions could be due to differences in either the stimulus conditions or the measurement procedures. Although no accommodative stimuli were present in the empty-field condition, the retinoscope may have provided a weak accommodative stimulus. If so, then the introduction of positive lenses before the subject's eye may have induced accommodation to adjust for a somewhat greater distance than the focus obtained with an empty field. Alternatively, the discrepancy may have resulted from differences between the two refraction techniques. Glickstein and Millodot\textsuperscript{15} have proposed that retinoscopy is biased toward relatively hyperopic measurements because the retinal reflex arises at the anterior surface of the retina rather than the receptor plane. This bias could not occur with laser refraction, since the measurement depends on the apparent motion of an interference pattern in the plane of the receptors. Also, one should note that the subjects' tasks were very different for the two measurement techniques. For near retinoscopy, the subject freely viewed a moving light source while various lenses were placed before the eye. During the laser measures, the subjects judged the appearance of a briefly flashed laser pattern while viewing a blank stationary field through an artificial pupil.

Whatever the cause for the difference between near retinoscopy and empty-field refractions, the data in Fig. 1 indicate that accommodation during near retinoscopy is closely related to the subject's resting focus. This finding implies that the retinoscope beam and the interposed lenses have relatively little effect on accommodation. The second experiment was conducted in order to provide a more direct test of the influence of the retinoscope beam on accommodation. A single measurement technique, the laser optometer, was used to assess refraction while subjects viewed a stationary retinoscope and a matrix of Snellen E's, each presented over a range of distances. Measures of the resting
focus of accommodation were again taken while the subjects viewed an empty field. In this experiment, all stimuli were viewed monocularly through an artificial pupil.

Fig. 2 presents the results of experiment II after averaging across subjects. The mean accommodative responses for the retinoscope (dashed line) and the letter matrix (solid line) are given as functions of viewing distance. When plotted in this format, accurate focusing responses would result in a function of unit slope; the absence of an accommodative response would result in a horizontal function with an intercept near the mean empty-field refraction, which is indicated by the arrow at an ordinate value of $-1.56$ D. Although the letter matrix elicited fairly accurate focusing responses, variation of the distance of the retinoscope produced little change of accommodation. Accommodation for the retinoscope remained near the average resting state value ($1.56$ D), varying by only $0.3$ D. In contrast, variation of the optical distance of the letter matrix over the same range resulted in a $2.2$ D change in mean accommodation. Thus, although the subjects were capable of normal accommodative responses, the retinoscope did not elicit such behavior. The following experiment was conducted to determine whether this finding also held true for infants.

**Experiment III**

Near retinoscopy was performed on infants and toddlers from four different distances to determine whether babies as well as adults fail to accommodate accurately for the light source of a retinoscope. It was reasoned that the obtained measures should vary systematically as a function of working distance if either the retinoscope or the presence of the retinoscopist influenced the infants' accommodation.

**Subjects.** Eleven healthy children from 1.5 to 26 months of age (mean 9.8 months) served as subjects.
**Procedure.** Near retinoscopy was performed twice on each infant from 100, 50, 33, and 25 cm, once in a series of increasing distances and once in a series of decreasing distances. The order of working distances was counterbalanced across subjects. To minimize the possibility of measurement bias, an assistant manipulated the lens bar in front of the infants' eyes and recorded the lens powers required for a neutral reflex without informing the retinoscopist of these values. The obtained measures were later corrected for working distance, but as in the first experiment, the usual near retinoscopy tonus correction was not used. Thus the corrected measures represented the infants' refractive state during the near retinoscopy procedure.

**Results and discussion.** Fig. 3 presents the mean refractive state of the 11 infants during near retinoscopy as a function of working distance (dashed line). A solid diagonal line indicates the refraction that would have resulted if the infants had accommodated for the plane of the retinoscope. These data show that the infants' refractive states were nearly equivalent for the 100 and 50 cm working distances whereas increasing accommodation was obtained for the 33 and 25 cm working distances. Thus, as with adult subjects, the infants never accommodated accurately for the plane of the retinoscope. However, unlike the adults, the infants showed some increase of accommodation for the two nearest working distances. One possible cause for this increased accommodation was the influence of convergence. Contrary to the procedure followed with adult subjects, the untested eye of infant subjects was not occluded effectively. Therefore they may have converged as working distance decreased, producing a consensual increase of accommodation. Although additional data will be necessary to test this hypothesis, the present results indicate that the near retinoscopy procedure has little influence on the accommodation of infants when performed from a working distance of 50 cm or more.

**General discussion**

The present findings indicate that the light source of a retinoscope is not an effective stimulus for accommodation. Adult subjects, who accommodated accurately for a complex stimulus pattern (Snellen E's), tended to remain near their resting focus when viewing the retinoscope (Figs. 1 and 2). Similarly, the refraction of infants did not vary appreciably as the working distance for near retinoscopy was varied from 100 to 50 cm. These findings are in agreement with those of an earlier experiment which showed that a monocular fixation point is not an adequate accommodative stimulus, and they suggest that more complex, contoured stimuli may be necessary to elicit accurate steady-state accommodation. Recent studies have re-emphasized the fact that accommodative responsiveness depends heavily on the spatial characteristics of the retinal image.

The present experiments confirm earlier clinical observations that accommodation remains stable during near retinoscopy. As with other refraction techniques that control accommodation by eliminating or greatly reducing accommodative stimuli (e.g., some infrared refractometers), most subjects exhibited anomalous myopia during near retinoscopy. This excessive refractive power reflects a shift of accommodation toward the subject's intermediate resting focus under reduced
On the average, this effect can be compensated by application of a standard tonus adjustment to the gross static refraction obtained by near retinoscopy (experiment I). However, one should remember that, as with cycloplegic refractions, the average tonus adjustment is not ideal for all individuals. Subjects who have a relatively near resting focus would probably benefit from a tonus correction greater than +0.75 D, and those who have a relatively far resting focus would probably benefit from a correspondingly smaller tonus adjustment. Therefore subjective confirmation of the near retinoscopic refraction should be obtained whenever possible.

We should emphasize that near retinoscopy differs in several basic respects from dynamic retinoscopy techniques. Most importantly, the stimulus conditions employed are quite different. Although the filament and exit aperture of the retinoscope are the only visible stimuli during near retinoscopy, a binocular, contoured fixation target (e.g., Jaeger optotypes) is usually used for dynamic retinoscopy. Although this latter procedure is useful for tests of accommodative facility, the appropriate reading “add” for presbyopes, or the depth of cycloplegia, the use of dynamic retinoscopy for obtaining distance refractions is complicated and often imprecise. These difficulties are probably the result of complex interactions between accommodation, convergence, and variations of the stimulus conditions. Convergence for the binocular fixation target would be expected to induce some degree of “convergent accommodation” that may be independent of the distance refraction and may vary from one patient to another. Moreover, even the monocular accommodative response for near stimuli usually “lags” to a degree that varies across subjects and stimulus conditions.

Near retinoscopy obviates these difficulties by minimizing the stimuli for accommodation and convergence. Consequently, accommodation tends to remain near the individual’s resting focus throughout the measurement procedure.

The near retinoscopy technique provides at least two unique advantages over other clinical methods of refraction. Of primary importance, it offers a rapid and reliable method for refracting nonverbal subjects without the use of drugs. Near retinoscopy has permitted repeated testing of infants and young children in longitudinal studies of the development of visual acuity and refractive error, and it has also been successfully used to refract infants for whom cycloplegics might be contraindicated. Systematic evaluations have consistently shown near retinoscopic measures to be reliable, and the present evidence indicates that this technique gives a useful estimate of the intermediate resting state of accommodation.

The second advantage of near retinoscopy concerns the prediction and correction of anomalous “myopia” which many adults suffer under reduced stimulus conditions. The tendency of emmetropic and corrected ametropic observers to become myopic under low illumination (i.e., night myopia) is a common problem that now goes untreated. Recent research has shown that this phenomenon and similar anomalous myopias which occur in bright empty fields (space myopia) and when using optical instruments (instrument myopia) can be explained as the return of accommodation to its intermediate resting focus. Other experiments have demonstrated that both night myopia and empty-field myopia can be optically corrected on the basis of the individual’s intermediate resting focus. The present study shows that before application of a tonus adjustment, near retinoscopic measures provide a good estimate of the subject’s characteristic resting focus. Thus near retinoscopy may represent a convenient method for predicting and correcting night myopia and related phenomena with equipment that is readily available to the clinician.

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REFERENCES

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