Reports

Accommodative Hysteresis: A Precursor for Induced Myopia?

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After an 8-min fixation period, the dark focus of accommodation of 12 emmetropes either increased by −0.34 diopters (D) or relaxed by 0.21D depending upon whether the fixation target was at the near point or far point, respectively. No significant shifts occurred after fixation at the distance of the subject’s dark focus. The obtained shifts had long time-constants as measured after 16 min in darkness. Decay was much slower after near point (τ = 123.1 min) rather than far point (τ = 14.4 min) fixation. Invest Ophthalmol Vis Sci 24:513–515, 1983

Hysteresis in accommodation refers to the incomplete relaxation of accommodation after a period of fixation, the final level of accommodation reflecting the direction and magnitude of the accommodation stimulus in force during the fixation period. Although some evidence for such effects does exist, little is known of the factors on which they depend nor of the time course of recovery from the hysteresis effect. The present study examined these effects by measuring changes in the dark focus of accommodation before and after an 8-min period of sustained accommodation.

Materials and Methods. Subjects were 12 student volunteers who had Snellen acuities ranging between 20/15 and 20/25, wore no spectacles, and had no known visual defects. The resting level of accommodation or dark focus was measured with a laser optometer patterned after that of Hennessy and Leibowitz,3 represented in Figure 1. The rotating drum was displaced by an electronically controlled stepping motor in 1 cm steps corresponding to 0.16 diopter (D) increments until the observer reported a reversal in direction of flow of the speckle pattern. After the second response consistent in direction with the first reversal, the drum was displaced in the opposite direction until a reversal and one additional consistent response again was made. In this fashion the “no-motion” range was bracketed, the center of the range representing the observer’s dark focus of accommodation. The collimated and expanded (X5) beam from a 2 mW He-Ne laser was observed monocularly with the right eye for 500 ms after reflection from a slowly rotating drum. A 4D Badal lens placed at 25 cm from the eye assured constant brightness and size of the speckle pattern with changes in its optical distance.

The dark focus was calculated in diopters after corrections were made for chromatic aberration of the monochromatic laser stimulus (632.8 nm)4 and for the plane of stationarity relative to the drum axis, ie., the position of the plane containing the conjugate point to the retina, when the speckle pattern appears to be stationary.2 A second lens (8.33D) at 12 cm also maintained the fixation target at constant size and brightness. This target, also shown in Figure 1, was visible only during the 8-min fixation period and was used to determine the subjects’ near and far points respectively. Subjects were encouraged to maintain the target, especially the vertical line segments, in sharp focus while it was moved slowly toward or away from the observer to the point of blur. It was then moved in the opposite direction until a sharp image was reported. Measurement was possible from optical infinity, with the target placed at the focal length of the lens, to a maximum near point approaching the diopter value of the lens with the target in the plane of the lens. The target was illuminated with light from a 50 w Tungsten-Halogen source and had a luminance of 75 cd m².

All subjects participated in four sessions separated by at least 24 hrs. In the first session far acuities were taken and two training session dark focus measurements were made. At the remaining three sessions subjects provided two dark focus measures in succession, the second of which was taken as the dark focus reference level for that session. There followed an 8-min target fixation period with the target either at the observer’s near point (NP), far point (FP), or at the distance of the dark focus (DF) itself. A post-fixation dark focus measure then followed about 30 S after the target light was turned off. This was repeated 8 min after the termination of the target and again at 16 min. These intervals were spent in complete darkness and provided the basis for the assessment of the rate of decay in the hysteresis effect. All six of the possible three-element sequences of the three fixation conditions were represented twice in the 12-subject group. Ages ranged from 18 to 24 years.

Results. Accommodative hysteresis: The main question is whether or not a period of maintained accommodation subsequently biases the resting level of accommodation. The difference in dark focus measurements between pre- and post-fixation periods...
Fig. 1. Laser optometer used for the measurement of accommodation in darkness. One side of the square target used during the fixation period projected 2.38 × 0.10 deg of arc at all optical distances. When fixating the central point, the edges of the line segments all fell within 1 deg of arc at the fovea.

shown in Figures 2A–C clearly indicates the presence of hysteresis effects. The left-most bar represents the dark focus reference level in a given session. These are very similar in magnitude to the averages reported by Leibowitz and Owens. The remaining bars are shown as changes from the reference level and are indicative of the hysteresis effects. Note that with near point fixation there was a significant increase of 0.34 negative diopters, \( t(11) = 4.25, P < 0.01 \), whereas a nonsignificant shift of −0.06D occurred with dark focus fixation, \( t(11) = 1.50, P > 0.05 \). In contrast, fixation at the far point yielded a dark focus level reduced by 0.21D that also was significant, \( t(11) = 4.20, P < 0.01 \). These results were highly reliable in that 10/12 observers showed an increased DF in the NP condition, 11/12 showed a decrease in the FP condition, while 7/12 in the DF condition became more negative, 4/12 more positive, and one showed no shift at all. Observers K.K. and J.O. represented in the lower half of Figure 2 demonstrate the same pattern of results for the highest and lowest pre-exposure dark focus levels in the entire sample.

The large variation in pre- to post-fixation shifts in DF indicates the presence of substantial individual differences in susceptibility to accommodative hysteresis. Increments ranged from 0.240 to −0.800 in the near-point condition and from −0.160 to 0.400

Fig. 2. Dark focus levels for pre- and post-fixation periods. Fixation was at the near point in panel a, the distance of the dark focus in panel b, and the far point in panel c. The right-hand axis represents increments in the post fixation dark focus with prefixation level as reference.
after far-point fixation. There was, in addition, no significant correlation between hysteresis effects obtained in the FP and NP fixation conditions (r(10) = 0.189, P > 0.05). Despite these individual differences and the absence of correlated effects, dark focus measures themselves were highly reliable. Thus, the correlations between the prefixation DF measures used as reference levels at the three sessions were 0.951 (NP vs FP), 0.898 (NP vs DF), and 0.863 (FP vs DF). All were significant at P < 0.01, and are consistent with previous measures of dark focus stability.\textsuperscript{7}

In an absolute sense the NP shift (~0.34D) was greater by about 62\% than the FP effect (0.21D). It would seem not unreasonable to expect these magnitudes to be proportional to the departure of the fixation target distance from the prefixation dark focus. In the NP condition the target was, on average, 5.12D closer than the dark focus, whereas in condition FP, the target was at 0.98D beyond the DF. Thus, one might have expected the NP effect to be about five times stronger than the FP effect. Accordingly, the FP effect may be regarded as considerably stronger than the simple proportional model would predict. Such a nonlinearity would be expected if there were separate systems governing accommodative increase and relaxation respectively with each having separate gain constants.\textsuperscript{8} In this respect the recent report\textsuperscript{9} of the absence of a significant correlation between the resting point and the near point of accommodation together with the presence of a significant correlation between the former and the far point is further support for the existence of independent subsystems.

**Decay time constants:** Near and far-point decay rates appear to be quite different. After 16 min the near-point increment diminished to only 88\% of initial value whereas the far-point shift had dropped to 33\% of the post fixation value. Assuming an exponential decay function that asymptotes in five time constants, the far-point effect would dissipate in 72 min whereas the near point shift would require 10.26 hrs.

**Discussion.** Accommodative hysteresis has been shown to result from a modest 8-min fixation period. This represents a type of plasticity for the dark focus also found in the disparity-vergence system.\textsuperscript{10,11} In both cases the effects represent a change in the “set point” of the system regulating steady state tonus levels.

Results of the 16-min decay period suggest surprisingly long-time constants that, significantly, are greater for the NP than for the FP fixation conditions. While it is too early to tell precisely the functional significance of these effects, the extraordinarily long decay time constants associated with near-point fixation suggest a potentially important role in the etiology of axial myopia. Since accommodative hysteresis implies a long lasting increase in ciliary muscle tonus, it is conceivable that the propensity toward hysteresis effects is related to the incidence of near-work induced myopia.\textsuperscript{1,12} The mechanism linking hysteresis effects with axial growth, however, remains speculative.\textsuperscript{13,14}

**Key words:** accommodation, hysteresis, dark focus time constant

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