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Stability of the Accommodative Dark Focus After Periods of Maintained Accommodation

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The behavior of the accommodative system at rest was investigated following short- (5 min) and long-term (1 hr) accommodative stimuli of either 0.00 D or 3.00 D. The resting position of accommodation changed in the direction of the accommodative stimulus presented. After the 5 min stimulus, the resting position slowly returned toward the pre-stimulus level. After the 1 hr stimulus, the resting state remained significantly different from the pre stimulus level over the subsequent 6 hr. These results suggest that the equilibrium level of accommodation in the dark is determined by a balance of the previous accommodative stimuli. Invest Ophthalmol Vis Sci 27:1414-1417, 1986

The concept of an intermediate resting position of accommodation is not new, and has emerged to modify the classical theory which states that, when the eye is at rest, accommodation is relaxed such that the retina is conjugate with an object at infinity.1 The definition of a resting state in Morgan's interpretation is the state of the reflex arc when afferent activity (visual activity in this case) is unstimulated.2

The state of accommodation in the dark, more popularly known as the dark focus, is assumed to be a stable dark focus, data showing the presence of individual fluctuations and intra-subject differences are evident. This variability in the dark focus suggests that there may be uncontrolled factors which have an effect on the dark focus. For example, the mean dark focus value is less for myopes than for hyperopes, with emmetropes having a mean that is in between.7

Recently, Ebenholtz8 has shown that the accommodative state immediately prior to measurement influences the dark focus. In this study, we investigated the temporal behavior of the dark focus as it is changed to a new level with different stimulus strengths and duration.

Materials and Methods. The laser optometer9 was used to measure the dark focus position of accommodation (Fig. 1). The beam from a 0.95 mW laser of wavelength 632.8 nm was diverged by a −20.00 D lens and reflected off a mirror to create a speckle pattern on the surface of a drum, 3.3 cm in radius. The orientation of the mirror was such that the center of the reflected beam bisected the optical axis of the optometer at the drum surface.

The drum was rotated at 0.93 rpm by a two-way motor. A forced-choice random double staircase method10 was used to find the dark focus. A headrest was used to maintain a fixed head position during the experiments. An electronic timer operating a shutter limited the exposure of the pattern to 0.44 s; when the speckle pattern is exposed in this way, it is not a stimulus to accommodation.11 Optometer readings were converted into dioptric measures with the inclusion of a chromatic correction of +0.33 D12 for the eye's chromatic aberration.

The stimulus targets consisted of rows of 5' arc Snellen letters. This angular subtense was maintained when the task called for different testing distances. The target was placed in alignment with the speckle pattern seen through the beam splitter, and the accommodative response of the subject to the stimulus was measured. A relay dimmed the illumination on the target when the speckle pattern was exposed.

The subjects were either emmetropes or myopes aged...
between 21–25 yr. The tests were done in the monocular situation, and a 3.5 mm pinhole was placed at the spectacle plane of the subject only during measurement of the dark focus. The pinhole served to enhance the observation of the speckle pattern and also to reduce the spherical aberration of the eye. This dual advantage helped to minimize the zone of neutrality. All volunteers were trained subjects, having participated in this type of experiment previously.

The experiment consisted of two main parts. In the first part, we investigated the short-term behavior of the dark focus following changes in accommodation and the effect of a subsequent stimulus of opposite strength on the new dark focus level. In the second part, we investigated the magnitude and the temporal variation of the dark focus following a prolonged period of accommodation.

**Part 1:** Dark focus levels were measured at 5 min intervals for 15 min following predetermined stimulus levels. A reference dark focus level was established at the start of the experiment before introducing any stimuli. The effect of a −3.00 D stimulus on the dark focus level was studied first, followed by a 0.00 D stimulus. At another sitting, having established a reference dark focus level, the same subject was given the 0.00 D stimulus first and then the −3.00 D stimulus. A total of six trained subjects were used for these experiments.

**Part 2:** This experiment investigated the effect of prolonged stimuli on the dark focus level of four subjects. A headrest was not used here, since the subjects found it uncomfortable to maintain a fixed position for an hour. Two stimuli were used. For the −3.00 D stimulus, subjects were required to read a book of letter size, 2–3 mm high, held at 33 cm from the eye for an hour. For the 0.00 D stimulus, +3.00 D was placed at the spectacle plane and the book held at 33 cm. The distance was measured at 10 min intervals to ensure that the subjects maintained the book at the distance required. We used this procedure to avoid changing the target configuration between the two experiments.

After the 1 hr stimulus, the dark focus level was measured over the next six hr. Subjects remained in the dark for the whole of this six hr period.

**Results.** The results of experiment 1 are shown in Figure 2. The effect of a 5 min increase in accommodation above the reference dark focus level was to create a new dark focus level which is higher than the reference level. The dark focus remained significantly elevated for 15 min (P < 0.05). The subsequent 0.00 D stimulus initially lowered the dark focus point. However, this shift was not maintained, and accommodation appeared to return towards the more recent dark focus level with time. It then levels off in between the −3.00 D dark focus level and the reference dark focus level. The difference between dark focus levels produced by the −3.00 D stimulus (20 min) and the 0.00 D stimulus (40 min) is statistically significant (P < 0.05).

The results of the reverse-order experiment (0.00 D followed by −3.00 D stimulus) are shown in Figure 2B. The 0.00 D stimulus lowered the dark focus level significantly (P < 0.05) for the duration of the test. The −3.00 D stimulus that followed increased the dark focus point initially, but, with time, this returned toward the dark focus level set by the 0.00 D stimulus. It was significantly different from the dark focus of the 0.00 D stimulus (35 min) only at the 40 min measurement.

The results of experiment 2 are summarized in Figure 3. Maintaining accommodation at 3.00 D for 1 hr produced a mean shift of 0.95 D (SD 0.78) in the dark focus, while the 0.00 D stimulus produced a mean shift
of 0.73 D (SD 0.55) after 1 hr. These changes are significantly greater than those produced by the 5 min accommodative stimuli in experiment 1.

After removing the stimulus, the dark focus was monitored over the next 6 hr. With subjects 1 and 2, the new dark focus level was relatively stable over the 6 hr measured following both the −3.00 D and the 0.00 D stimulus. Dark focus “decay” was present for both the stimuli for subject 3. This is apparent after the first hour for the −3.00 D stimulus and after the

Fig. 2. The effect of accommodation on dark focus (DF). Between t = 0 and 15 min, a reference DF was determined. A, between t = 15 and 20 min, a 3.00 D accommodative stimulus was given, and DF then measured t = 20 and 35 min. Between t = 35 and 40 min, a 0.00 D accommodative stimulus was given. DF was then determined for the next 15 min. Each point is the average of the results of six subjects. Average SDs for data points were 0.36 D. B, As for A, but the accommodative stimulus were presented in reverse order.

Fig. 3. The temporal behaviour in dark focus (DF) following 1 hr of maintained accommodation. At time = 0, the accommodative stimulus was removed, and DF was determined over the next 6 hr. Two maintained accommodative stimuli were used: −3.00 D (●), upper curves and 0.00 D (○) lower curves. Prestimulus dark focus values are indicated as (●) for the experiment using the −3.00 D stimuli and (○) for the 0.00 D stimuli. Vertical bars indicate ±1SD. A, Results for subject 1; B, results for subject 2; C, results for subject 3; and D, results for subject 4.
second hour for the 0.00 D stimulus. At the sixth hour, the dark focus shift was still significantly different (P < 0.01) from the pre-experiment level. Subject 4 showed a slow rise in dark focus level following the 0.00 D stimulus and an immediate decay after the −3.00 D stimulus. Six hours following the 0.00 D stimulus, dark focus had returned to its pre-experiment level. After the −3.00 D stimulus, dark focus was still significantly elevated 6 hr later.

**Discussion.** We confirm that the dark focus position of accommodation is influenced by the preceding state of accommodation of the individual, as shown previously by Ebenholtz.8

In our first experiment, maintaining accommodation at either 3.00 D or 0.00 D for 5 min produced a shift of about 0.4 D in the dark focus. This shift was not maintained, but decayed with a half-life of about 15 min toward the level prevalent immediately before the 5 min stimulus.

These results pose the interesting question of whether there is a basic, fixed, dark focus level for an individual, as suggested by Leibowitz and Owens,3 or whether the prevalent dark focus is simply determined by the accommodative history preceding measurement.

We attempted to answer this question in our second experiment. If accommodative history was the sole determinant of dark focus, then a relatively prolonged period where accommodation was maintained at a fixed level should produce a new, maintained dark focus. Two of our four subjects displayed exactly this behavior. After 1 hr of maintained accommodation, dark focus was shifted to a new level, and was maintained there for a 6 hr period where visual accommodative clues were absent. Two other subjects also showed similar large shifts in dark focus following prolonged maintained accommodation, but with a very slow decay (half-life about 3 hr) toward their 'normal' dark focus.

The most obvious conclusion from these findings is that the rate of decay of dark focus depends on the historic dark focus, and on the period for which a new accommodative level is maintained. If this new level is maintained for a sufficient time, then our results suggest that the decay rate would become practically zero. In other words, while the dark focus shows some individual idiosyncrasies, it is essentially determined by the accommodative history.

**Key words:** accommodation, dark focus, laser optometer, accommodative stability

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**References**


**Infants’ Acuity at Twenty Feet**

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Measurement of duration of fixation was used to assess the ability of 6-, 12-, 24-, and 36-week-old infants to discriminate black-and-white square-wave gratings from a homogeneous gray field at a distance of 20 ft (6.1 m). Acuity was estimated as the smallest stripe width detectable by at least 18 of the 24 infants in a given age group. The stripe width was considered detectable if it was fixated longer than a homogeneous gray field. The results are consistent with estimates of infants’ threshold acuity obtained at target distances less than 5 feet (1.5 m). Because of the 20-ft viewing distance, these infants’ acuity in Snellen notation can be more confidently estimated. Invest Ophthalmol Vis Sci 27:1417–1420, 1986