EFFECT OF ACCOMMODATION ON THE RETINAL IMAGE*

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In text-books on physiological and visual optics we find two diametrically opposed statements.

(1) Some texts say, to quote one as an illustration:

The size of the retinal image varies directly as the distance of the second nodal point from the retina. Since the optical effect of accommodation is to increase this distance it is accompanied by an increase in the size of the retinal image.

(2) Other texts say, again to quote one as an illustration:

In accommodation the dioptric power (of the eye) is increased . . . The retinal image, therefore, is decreased in size during accommodation.

The latter text also adds that, in Gullstrand's eye, the posterior nodal point comes forward from 7.332 to 6.847 mm. (during accommodation). Because of this some writers state that the retinal image increases in size during accommodation. They fail to take into account that while the posterior nodal point advances 0.485 mm. the posterior principal focal point advances 3.855 mm.

These two statements, to which we shall refer as Statement 1 and Statement 2, while seemingly contradictory, are each partly true, though neither is complete. The first says that accommodation increases the size of the retinal image, that is it makes the image "larger", but larger than what? The second says that in accommodation the retinal image is decreased in size, that is the image becomes "smaller", but smaller than what?

Let us first note that there are several kinds of images in the eye. The two we will consider here are:

(i) the optical image
(ii) the retinal image.

The optical image is the clear focused image formed by the optical system of the eye. In emmetropia, for a distant object, this image falls on the retina and becomes also the retinal image. In myopia it falls in front of the retina. In hyperopia it falls (or tends to fall) behind the retina.

The retinal image is that which falls on the retina. It may be clear or blurred. Its size when blurred may be taken from the point in the diffusion circle where the ray along a secondary axis (through the nodal point) strikes the retina. There are other methods of calculating the size of the blurred retinal image, but they are not pertinent to our present discussion. We will ignore for the present the enlargement due to the diffusion circles.

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Two optical facts agreed on by all are:

(i) The object and its retinal image, clear or blurred (as defined above), make equal angles at the nodal points: object at N1, image at N2. We may consider the two nodal points to be coincident and refer simply to the nodal point.

(ii) The stronger the optical system, simple or compound, the smaller the real optical image formed by that system.

Now, Statement 1 holds good for the retinal image; this is made larger by accommodation, but larger than what? Take an emmetropic eye viewing a distant object and call the size of the (clear) retinal image x. If the eye viewing the same distant object accommodates, say, 3.00 D., the retinal image of the object is now blurred and larger than x, since during accommodation the nodal point has moved forward. We may call this image y. Then y > x.

Suppose the normal emmetropic eye accommodates for an object 35 cm. away. It gets a clear retinal image of the object which we may call u. If the eye now relaxes all accommodation while viewing the same object at the same distance, a blurred retinal image is formed, which we may call v, and since in u the nodal point is further from the retina, u > v. Here too the retinal image during accommodation is larger than the retinal image during non-accommodation. All this conforms with Statement 1. But this comparison of a clear retinal image with a blurred retinal image of the same object at the same distance (blur and change in size being due to changes in accommodation) is not a very satisfactory comparison.

Turning to Statement 2, we may suppose that the normal emmetropic eye views a distant object. The optical image formed by the eye, which we may call m, is on the retina. We have here a clear retinal image. Suppose the eye while viewing the same distant object accommodates, say, 3.00 D. The refractive power of the eye has now increased by 3.00 D. and the optical image, which we may call n is now formed in front of the retina, and is smaller than the optical image m formed by the weaker refractive system (i.e., the non-accommodated eye). Thus n < m.

In this sense the size of the optical image of an object at distance during accommodation is smaller than the size of the optical image of the same object in non-accommodation. But we do not see with the optical image, but by the stimulus resulting from the retinal image. During accommodation for a distant object the blurred retinal image, call it y, is larger than x as was shown previously.

Similarly, suppose the eye views and accommodates for an object at, say, 35 cm. The optical image now falls on the retina, and its size may be called p. If the eye now relaxes its accommodation while still viewing the object at 35 cm., the optical image of the object, which we may call q, is larger than p (weaker refractive system). It is located behind the retina. But as the accommodation is relaxed and the nodal-point moves backward the retinal image (blurred) is smaller than the retinal image when the eye accommodated.
Thus Statement 2 is correct when referring to the optical image and is more complete when comparisons are made as outlined above.

However, the most logical way of noting the effect of accommodation on the size of the retinal image (the image by which we see) is to compare the clear retinal images which are obtained under the two sets of conditions. Thus, if a distant object subtends a $2^\circ$ angle at the nodal point of the static eye, the retinal image is clear and its size may be determined by the radian method as $I_D = \frac{2}{16.5}$ $\text{mm.}$ In this equation, $I_D$ is the clear image of the distant object, 16.5 the distance in mm. from the retina to the nodal point in the simplified schematic eye, and 57.3 the value of the radian angle; thus $I_D = 0.5759$ mm.

Now suppose an object subtending the same angle of $2^\circ$ at the nodal point of the accommodated eye is placed close to the eye and the eye accommodates for it. If the distance from the retina to the present position of the nodal point has increased to 16.8 mm., then $I_N = \frac{2}{16.8} = 0.5764$ mm.

In this equation, $I_N$ is the clear retinal image of the near object subtending the same visual angle; thus $I_N = 0.5864$ mm.

Thus the clear retinal image of a near object which subtends a given angle $a$ and for which the eye accommodates, is larger than the clear retinal image of a distant object subtending the same angle and seen without accommodation. This seems the most logical comparison and shows that accommodation increases the size of the retinal image. The proofs of the relative values given in this article can be found in any good text-book on physiological optics (e.g., Duke-Elder, 1940; Cowan, 1938).

**Summary**

The effect of accommodation on the size of the retinal image is given by some authors as an increase in size during accommodation and by others as a decrease in size during accommodation. One reason for this apparent contradiction is that the first group of authors refers to the retinal image, and the second group to the optical image; but both statements are incomplete in that there is no reference to the images compared. Several such comparisons are here discussed as well as the special significance of the retinal image. The most logical comparison is that made between the clear retinal image of a distant object subtending a given angle, and the clear retinal image of a near object subtending the same angle, for which the eye accommodates. In this way it may be shown that the retinal image during accommodation is larger than the retinal image during non-accommodation.

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