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itative Measurements of Relative Accommodation and Relative Convergence.

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ive relative accommodation (PRA) is the amount that ac-
lation can be stimulated toward a point nearer the eyes than
ated upon, and negative relative accommodation (NRA) the
accommodation can be stimulated toward a point more

PRA is measured by placing before the eyes concave
l lenses of increasing power until the small detail of the
target becomes blurred. NRA is measured by placing before
s convex spherical lenses until the detail is blurred. The
sic concepts are applied to relative convergence using prisms
of spheres. Generally PRC is measured by base-out prisms
ly increased in power until blurring of the target occurs and
measured by base-in prisms.

e are no quantitative data available as to the amount accom-

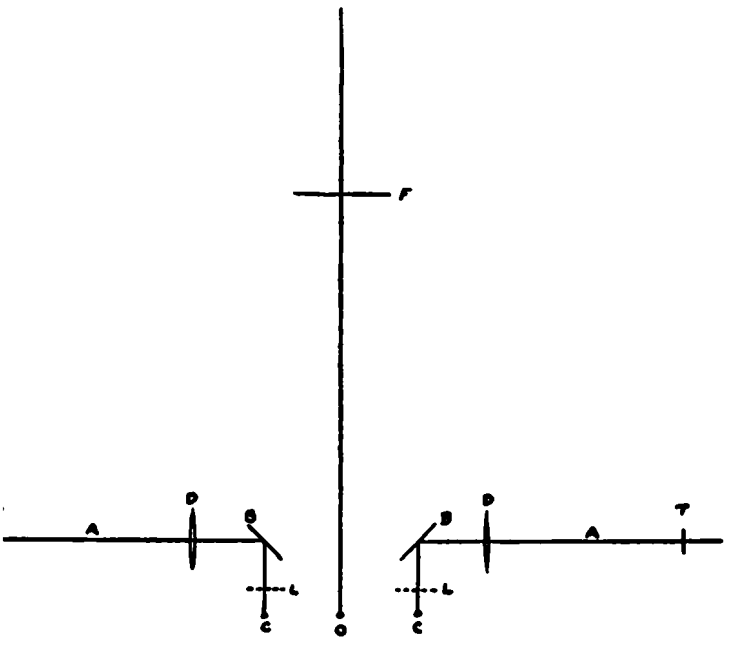

FIG. 1.

modation can be changed without changing convergence and vice versa. The limiting values used by refractionists have been arrived at empirically. The limiting point is said to be reached when the smallest letters on the chart have become too blurred to be read (blur-out).

We have endeavored to arrive at quantitative data by use of an haploscope* which is essentially a mirror stereoscope as shown in Fig. 1. It is made up of two arms *A* that are free to swing around a pivot *C*. Mounted at an angle of 45 degrees to the arms are half-silvered mirrors, *B*. On the arms, *A*, are 2 moveable targets, *T*, whose images are projected to any desired point by lenses, *D*. On these arms are also 2 lens holders, *L*. There is also a central arm on which is another moveable target, *F*, which the subject can see through the half-silvered mirrors. The distance between the pivots, *C*, can be varied to conform to the subject's interpupillary distance.

The targets, *T*, consist of small illuminated pin holes less than 0.2 mm in diameter. Also mounted behind the projection lenses, *D*, are 2 Scheiner discs. Thus when the pin point is conjugate to the retina the subject perceives only one small illuminated spot, but when the point is not conjugate to the retina the subject sees 2 spots.

The target, *F*, was photographically reduced Snellen type. The method used was to have the subject fixate the smallest line of print on the chart. Then the arms, *A*, were swung around their pivot points until the projected image of the target, *T*, was superimposed upon one of the letters of this line. While the subject binocularly perceived the target, *F*, the other target, *T*, was presented to one eye and adjusted until the small spot was seen singly.

PRA was stimulated by placing concave lenses in the lens holders, *L;* NRA by convex lenses; PRC by means of base-out prisms; and NRC by means of base-in prisms.

Forty-three subjects between the ages of 20 and 35 were used in this series of experiments. The accommodative amplitude of each person was greater than 5.00 diopters. No attempt was made to determine the refractive error of these individuals but no subject was included who showed signs of marked visual abnormality.

The data are plotted as shown in Fig. 2 for relative accommodation and in Fig. 3 for relative convergence. In Fig. 2 the horizontal axis shows the strength of the lenses that were added binocularly before the eyes so as to stimulate positive or negative accommodation, while the vertical axis indicates actual accommodative effort as de-

* Courteously loaned to us by F. L. Mason of Physics-Optometry Department of the University of California.

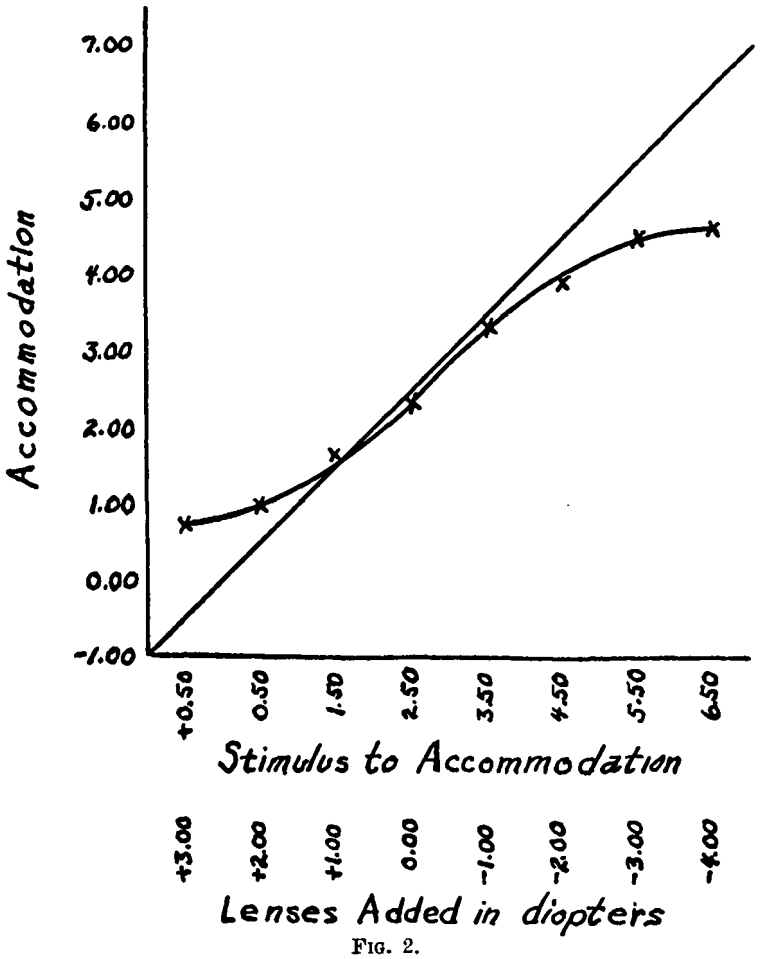

FIG. 2.

termined by the position of target *T*. The diagonal line represents the theoretical condition based on the assumption that there is a direct one-to-one change in accommodation with the lenses mounted before the eyes. Thus values falling below this line show that the eye was hypermetropic for the conditions of the measurement and values above it indicate that the eye was myopic.

In taking these tests the subjects were asked to report when the small letters were just barely blurred and when they were blurred so that they could no longer read them. The average value obtained for slight blur was +2.00 D. and for blur-out +3.00 D. in NRA; and —3.00 D. for slight blur and —4.00 D. for blur-out in PRA. The greatest variations were for values of slight blur, which ranged from

+1.00 D. to +3.00 D. and from —2.00 D. to —4.00 D. On the other hand, for complete blur-out the values varied from +2.25 D. to +3.00 D. and from —3.50 D. to —5.00 D.

It will also be seen that the curve appears to be approaching 2 asymptotes, the positive limit being approximately 4.75 D. and the negative limit approximately 0.75 D. of accommodation. Furthermore, the curve is almost a straight line between the values of 4.25 D. of accommodation and 1.50 D. of accommodation, or a total change in accommodation of 2.75 D. This change was induced by lenses ranging from —2.50 D. to +1.00 D. or a total change of lens power of 3.50 D. Therefore, between these limits the response of accommodation to the stimulus presented was about 80%.

The most logical interpretation is that 4.25 D. represents the upper limit beyond which accommodation cannot be stimulated without further convergence and that 1.50 D. is the point beyond which accommodation cannot be stimulated negatively without lessening the convergence. These values are, of course, not applicable to any fixation distance other than 40 cm. There was some evidence of change in convergence during the measurements.

It will be noticed from the graph that the eye may be more than 0.75 D. hypermetropic or myopic to the fixation point without experiencing noticeable blurring of the print.

Fig. 3 shows the results obtained for relative convergence. The horizontal axis shows the strength of the prisms that were placed before the eyes while the vertical axis shows the accommodation in force as measured by the position of target *T*. The straight line indicates the condition that would exist if there were no change in accommodation with a change in convergence. The data curve indicates that there is little change in accommodation as convergence is

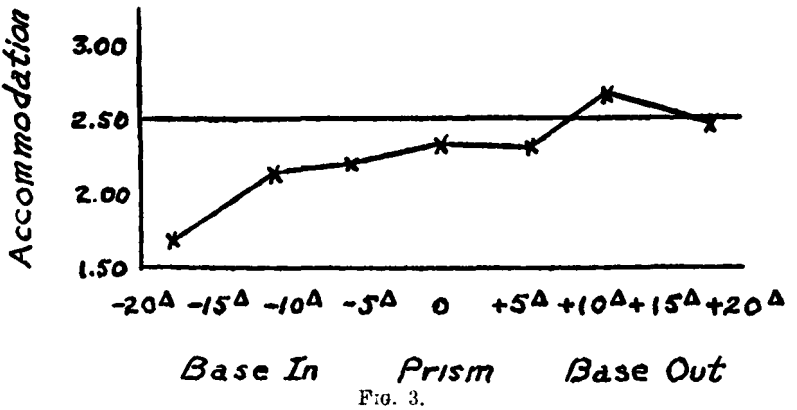

FIG. 3.

increased beyond that needed to fixate the target in the 40 cm plane, but that as convergence is decreased there is a rather sudden change in accommodation between the values of —11 prism diopters and —18 prism diopters.

The average points of blur-out were —14 P.D. for NRC and +16 P.D. for PRC. From the graph it is apparent that at —14 P.D. the eye is hypermetropic a little over 0.50 D., and at +16 P.D. the eye is emmetropic. This means that the blurring that occurs must be due either to the distortion of the target caused by the prism, or to the tendency of the retinal image to slip off corresponding areas in the retina.

The first explanation can be ruled out as it has been found clinically that the values obtained for positive and negative relative convergence, using a grill of horizontal lines as the fixated target, agree exactly with the values obtained using small type.

From —11 P.D. to +18 P.D. there is practically a straight line representation. There is a 0.33 D. change in accommodation with a 29 P.D. change in convergence. For practical purposes it can therefore be said that with each prism diopter change in convergence there is 0.01 D. change in accommodation between the limits of —11 P.D. and +18 P.D. relative convergence, assuming that convergence actually changes by the amount represented by the prisms.

Summary. The limits to which accommodation can be changed by interposition of spherical lenses without a change in convergence at a fixation distance of 40 cm are 4.75 D. and 0.75 D. From 4.25 D. to 1.50 D. the actual accommodation is 80% of the lens value used for stimulation.

Convergence cannot be changed without slightly changing accommodation. Between the limits of —11 P.D. and +18 P.D. this change amounts to 0.01 D. change in accommodation with each 1.0 P.D. change in convergence.