

STUDIES IN MONOCULAR AND BINOCULAR ACCOMMODATION, WITH THEIR CLINICAL APPLICATION

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In June, 1912, the author presented to the Ophthalmological Section of the American Medical Association a report summarizing the work he had carried on for five years on the amplitude of accommodation at all ages.* In the chart accompanying that report the values of the accommodations found in 2000 eyes were plotted, and from these values a curve was drawn showing the mean and also the maximum and minimum values found for the accommodation at each year of life.

These results showed certain important modifications of the mean curve obtained by Donders in his pioneer investigations made over half a century before. That the modifications were in general correct is deduced from the fact that the results obtained were derived from eight times as many cases as Donders used, and the tests, moreover, were made under conditions designed to insure rather greater accuracy. For example, Donders assumed that a middle-aged individual who had normal vision and did not accept a convex glass was emmetropic. This assumption we know is far from correct, such subjects often having a latent hyperopia of a diopter or more. The failure to recognize this hyperopia would obviously make the estimate of the accommodation in the subject tested just that much too low. In our own series of cases every subject up to the age of forty-seven was tested under homatropin, in order to determine the true refraction,

* "Normal Values of the Accommodation of All Ages," Jour. Amer. Med. Assoc., September 21, 1912.

and on the basis of this finding the results of the accommodative test were evaluated.

A more important difference between the two sets of observations was the fact that in our series observations were multiplied until it was possible to determine with some degree of certainty not simply the mean, but also the maximum and minimum values at each age. This was not possible with the comparatively few observations that Donders gathered.

The importance of determining these values, particularly the minimum at each age, is obvious. In measuring the accommodation in different patients of the same age we meet with wide variations. Clinically it is a matter of considerable interest for us to know, first, how wide these variations may be in normal cases; second, what the minimum limit is below which the accommodation at a given age must be regarded as subnormal. Both these questions are answered by the curves which we have plotted and the tabular values deduced therefrom.

These observations excited but little interest among ophthalmologists. It was felt apparently, as stated by one distinguished critic, that they did not differ essentially from those of Donders, or else, as another man, himself a most able observer, said, they were mere laboratory experiments and as such presumably inapplicable to the conditions of our office work. But both criticisms are invalid. The observations do differ materially and in a very practical sense from those of Donders; and they not only have a very important clinical bearing, but are readily applied in the routine of office work.*

Although in the main these observations have been confirmed by those made continuously since, it has been felt that they needed amplification in two regards: First, the

* See, for further, the paper cited, also the following further papers by the author: Importance of Testing the Accommodation as a Routine Measure in Refraction Work, *N. Y. State Jour. Med.*, December, 1912, and Anomalies of the Accommodation Clinically Considered, *Trans. Amer. Ophth. Soc.*, 1915.

observations at the very beginning and end of the series (below thirty and above fifty-five) were not numerous enough to afford absolutely certain indications as to the maximum and minimum limits. Second, they concerned only monocular accommodation. But as, clinically speaking, binocular accommodation is much more important than monocular, it seemed necessary to determine the former also and from an equally large number of cases.

Accordingly, the writer has collated the results of 5000 or 6000 observations taken since the original set was compiled, and has added to the latter the values of the monocular accommodation for over 2000 additional eyes. Furthermore, during the last two years he has made measurements of the binocular accommodation in some 500 cases, and has determined the relation that this bears to the monocular accommodation in each case. The results are shown in the accompanying charts and tables.

In making the measurements on which these charts and tables are based the same precautions were taken as in getting the original set.* These need not be rehearsed here. I will simply say that in each case the refraction was carefully determined, homatropin being used in all cases of forty-six or under and in some cases above forty-six; that repeated tests were made whenever possible, the near-point being determined by means of the fine-line test-object (Fig. 1) and the modified Prince's rule (Fig. 2), either with the full distance correction or with such determinate addition to that correction as would bring the range within measurable limits. In all cases the near-point was measured from the anterior focus of the eye (14 mm. in front of the cornea). Every precaution was taken to avoid error and to insure uniformity in methods used. Observations were discarded if repeated trials gave capriciously varying results or if tests made a year or so later gave higher values.

* Given in extenso in Jour. Amer. Med. Assoc., September 21, 1912.

MONOCULAR ACCOMMODATION

The values for the accommodation in each eye taken separately, as deduced from the examination of over 4200 eyes, are shown in Fig. 3,

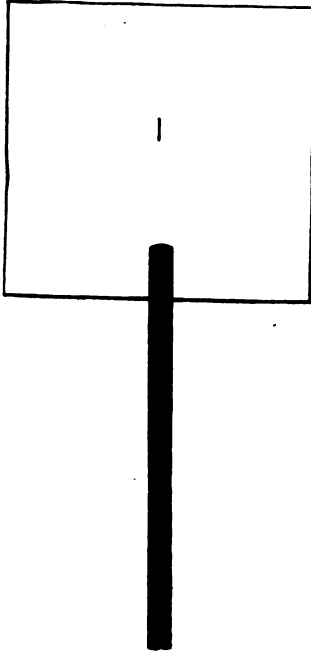


Fig. 1.—Accommodation line.

The test for the accommodation consists of a fine vertical line engraved on a card which is held in a suitable clip.

Fig. 2.—Accommodation rule.

This is a modified Prince's rule divided into centimeters and diopters. The notch at the end is slipped over the nose so that the zero point of the scale is placed 14 mm. in front of the cornea (practically in the plane of the patient's correcting glass). The accommodation line is carried along either side of the rule, to measure the accommodation of either eye separately, the other eye being closed, and along the top of the rule, to measure the binocular accommodation (in this case, of course, both eyes being left open). When the line is brought to the point where it just begins to blur or double, the distance of the near-point is read off in centimeters, or the corresponding accommodation is read off in diopters.

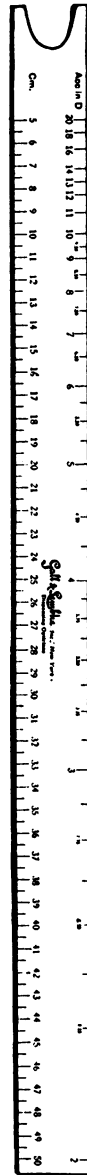


Fig. 2

and the maximum, mean, and minimum curves deduced from these values are shown in Fig. 4.

In making these charts we had to bear in mind that what

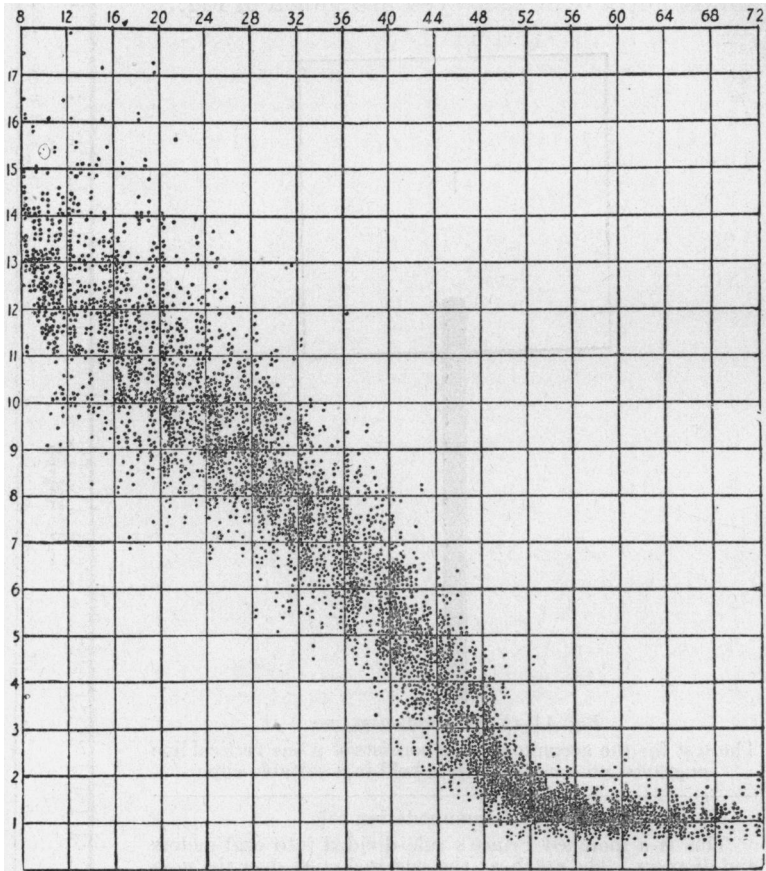


Fig. 3.—Values of monocular accommodation.

Each dot represents the maximum value in diopters of the accommodation in a given eye. The results obtained in over 4200 eyes are here plotted.

we are measuring in each case is not the average but the maximum amount of accommodation put forth by each individual. If, for example, a man at various times shows an

accommodation of 7.4 D., 7.8 D., and 9.D., and the tests in each case seem equally well authenticated, we say that his range is at least 9 D., the highest of the three measurements,

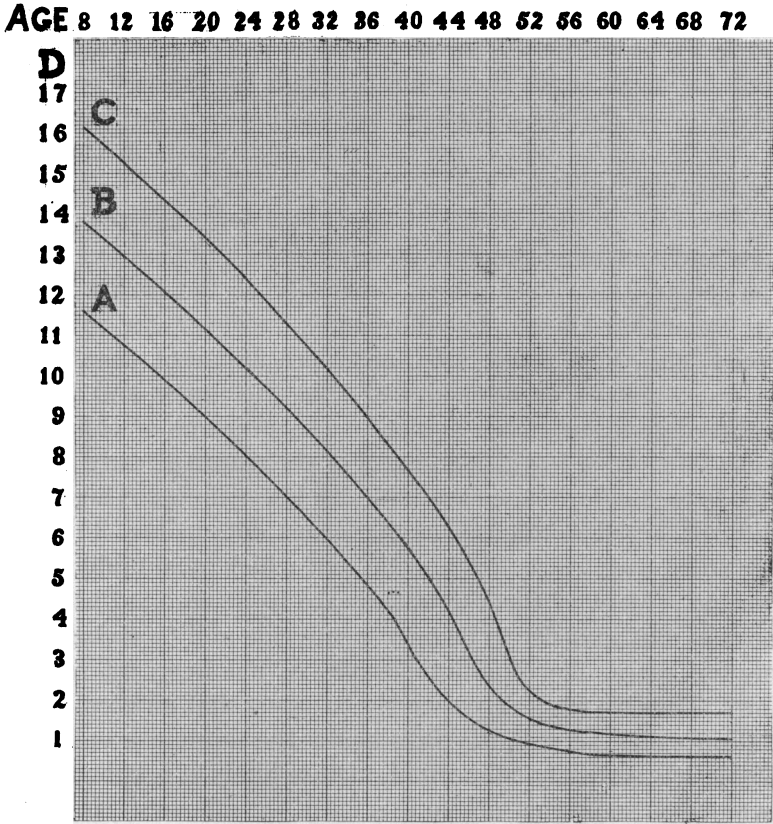


Fig. 4.—Accommodation curves.

These are deduced from Fig. 3. A, represents the extreme minimum, and C the maximum, limits of those dots in the whole mass represented in Fig. 3, which can be regarded as representing normal values. B is the curve representing the mean value of the accommodation.

instead of 8.1 D., or their mean. In fact, even the highest accommodation found in a given case may be and often is

below the patient's true maximum. Hence a great many of the dots shown in Fig. 3—especially those near the bottom of the mass—should probably be placed a little higher than they are, and hence also the curves drawn in Fig. 4, namely, the minimum curve A skirting the lower margin of the galaxy of dots, the maximum curve C, skirting the upper margin, and the mean curve B, passing through the densest portion of the mass, are put as high as they can properly be placed.

The values obtained for each age are given in the accompanying table (p. 139).

This table differs slightly from that determined ten years ago and reprinted since in a number of publications. In particular, the values given, especially at the earlier ages, are somewhat lower. The differences, however, are not material, and, in a sense, they are more apparent than real. It must always be remembered that the upper and lower limits determined from a plot of observations of this sort must be more or less indefinite. For the reason already given this is particularly the case with the lower limit. Thus it is difficult to tell in the case of the lowest dots in Fig. 3 which are to be counted as low normal and which as actually subnormal. Most of them doubtless are to be counted as subnormal, but in order to be on the safe side and to exclude no normal cases, the minimum curve, A, has been set rather low. Thus we are able positively to assert that an accommodation which persistently falls below the minimum value in Table 1 is certainly subnormal. Quite likely it is subnormal even when somewhat above this limit—at all events, it must be regarded with suspicion.

BINOCULAR ACCOMMODATION

In testing the binocular accommodation the same routine was used and the same precautions were adopted as in testing the monocular. In each subject the individual was provided with his full correction or with a known addition thereto.

Then the accommodation was taken with the accommodation line and the Prince's rule—first for the right eye, then

TABLE I.—TABLE OF ACCOMMODATION AT VARIOUS AGES
In diopters and tenths. Near-point reckoned from anterior focus of eye (14 mm. in front of cornea)

Age	Accommodation			Age	Accommodation		
	Minimum	Mean	Maximum		Minimum	Mean	Maximum
8	11.6	13.8	16.1	38	4.1	6.4	8.5
9	11.4	13.6	15.9	39	3.7	6.1	8.2
10	11.1	13.4	15.7	40	3.4	5.8	7.9
11	10.9	13.2	15.5	41	3	5.4	7.5
12	10.7	12.9	15.2	42	2.7	5	7.1
13	10.5	12.7	15	43	2.3	4.5	6.7
14	10.3	12.5	14.8	44	2.1	4	6.3
15	10.1	12.3	14.5	45	1.9	3.6	5.9
16	9.8	12	14.3	46	1.7	3.1	5.5
17	9.6	11.8	14.1	47	1.4	2.7	5
18	9.4	11.6	13.9	48	1.2	2.3	4.5
19	9.2	11.4	13.6	49	1.1	2.1	4
20	8.9	11.1	13.4	50	1	1.9	3.2
21	8.7	10.9	13.1	51	0.9	1.7	2.6
22	8.5	10.7	12.9	52	0.9	1.6	2.2
23	8.3	10.5	12.6	53	0.9	1.5	2.1
24	8	10.2	12.4	54	0.8	1.4	2
25	7.8	9.9	12.2	55	0.8	1.3	1.9
26	7.5	9.7	11.9	56	0.8	1.3	1.8
27	7.2	9.5	11.6	57	0.8	1.3	1.8
28	7	9.2	11.3	58	0.7	1.3	1.8
29	6.8	9	11	59	0.7	1.2	1.7
30	6.5	8.7	10.8	60	0.7	1.2	1.7
31	6.2	8.4	10.5	61	0.6	1.2	1.7
32	6	8.1	10.2	62	0.6	1.2	1.6
33	5.8	7.9	9.8	63	0.6	1.1	1.6
34	5.5	7.6	9.5	64	0.6	1.1	1.6
35	5.2	7.3	9.3	to 72		to 1	
36	4.9	7	9				
37	4.5	6.7	8.8				

Binocular Accommodation

The above are the limits for each eye tested separately. For binocular accommodation the values here given for the minimum and mean limits should be increased by 0.6 D. for ages 10 to 17; 0.5 D. for ages 18 to 31; 0.4 D. for ages 32 to 53; and 0.2–0.3 D. for ages above 53.

for the left, and lastly for both together. At the same time the width of the pupils was measured both when the eyes were converging to 25 cm. and to 10 cm. This was done in order to ascertain whether there was any truth in the con-

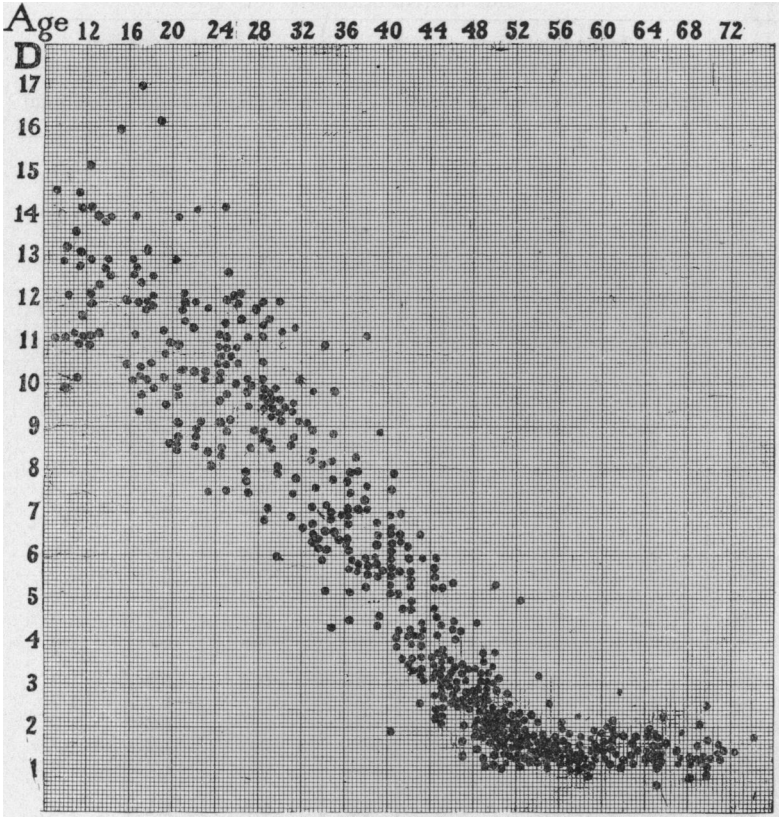


Fig. 5.—Values of binocular accommodation.

These are plotted in the same way as the monocular values in Fig. 3.

tention that any excess found in binocular over monocular accommodation is attributable not to real increase in accommodative action, but to a sharpening of vision due to the stenopæic action of pupils contracted by the convergence

effort. Lastly, the distance of the convergence near-point was noted and the presence of any motor anomaly, particularly the presence of any great amount of exophoria

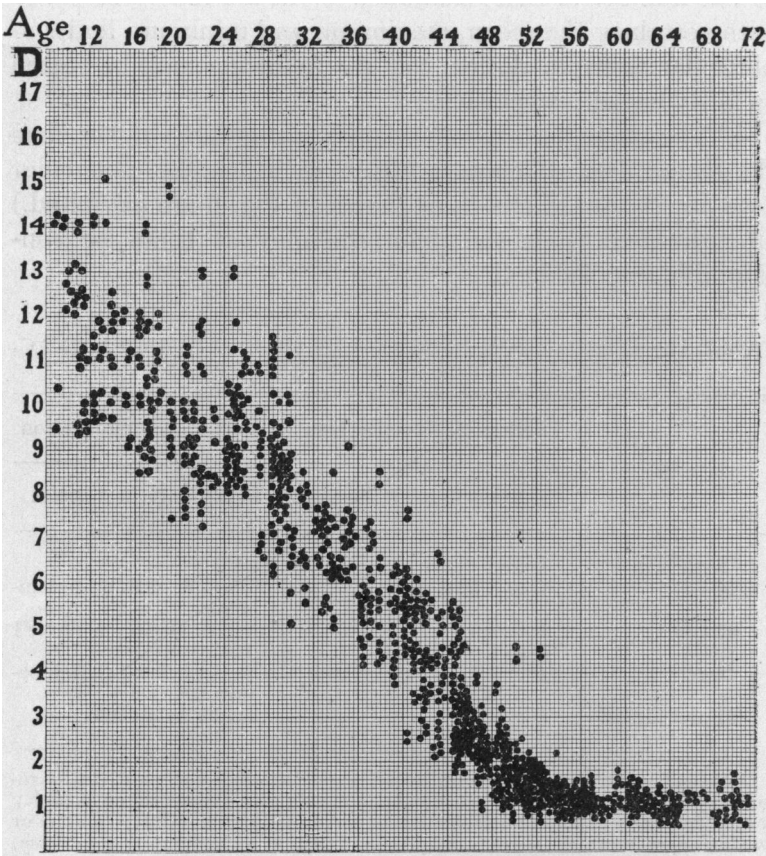


Fig. 6.—Comparison of monocular and binocular accommodation.

The spots here represent the values of the monocular accommodation in the subjects in whom the binocular values shown in Fig. 5 were determined. It will be observed how the general sweep of the galaxy of dots in 5 rises above that in 6.

in convergence or any condition interfering with binocular fixation or binocular vision at near-points.

The values thus obtained for the binocular accommodation, plotted on the same scale as that used for the monocular accommodation, are shown in Fig. 5.

The number of cases examined is yet too few to establish with certainty the mean, maximum, and minimum limits of binocular accommodation, yet the following may be stated as fairly certain conclusions:

1. The binocular accommodation is regularly higher than the monocular. (Compare Fig. 6, in which the monocular accommodation of the cases shown in Fig. 5 are exhibited.) In individual cases the difference may at times be considerable (see Table II).

TABLE II.—COMPARISON OF MONOCULAR AND BINOCULAR ACCOMMODATION AT DIFFERENT AGES

Age	Excess of Binocular over Monocular Accommodation	
	Extreme limits in diopters	Usual limits in diopters
8-15	0 to 6	1 to 2
16-34	0 to 3 or 4	0.5 to 1.5. 1 D. quite common
35-38	0 to 2.5	0 to 1.5. Usually not over 1
39-44	0 to 2	Usually not over 1
45-50	0 to 1.4 (in one instance 1.75)	Usually below 1; often below 0.8
51 and higher	0 to 0.9	Usually below 0.5

Note.—The extreme differences noted above are in some cases to be regarded with suspicion, it being likely that the subject's observation was faulty or that he failed in the monocular test to put forth his full effort. In one or two instances, however, there is no question but that a considerable difference, *i. e.*, one of several diopters, existed.

2. The excess, although varying greatly in different cases and even in the same case at different times, is quite constantly present. There are but few cases in which the binocular accommodation is not notably superior to the monocular; and even when the two seem to be equal, as shown by one

measurement, a repetition of the test usually shows that the binocular accommodation is the higher.

3. Only in the rarest instances was the binocular accommodation found lower than the monocular, and even these few cases are open to suspicion, since the values then found were generally deduced from but a single observation and the conditions were such as not to insure accuracy.

4. While the individual differences between the monocular and the binocular accommodation may run up to 1.5 D. or more, the average difference deduced from the entire mass of observations is a comparatively moderate one. Thus the values tentatively derived for the mean value and the minimum limit of the binocular accommodation are, for ages between ten and seventeen, about 0.6 D.—0.7 D. higher than for monocular vision; while from eighteen to thirty-one the difference amounts to 0.5 D.; from thirty-two to fifty-three, to 0.4 D., and for higher ages, to 0.3 D.

5. The excess of the binocular over the monocular accommodation is not in ordinary cases attributable to the clearer vision produced by the contraction of the pupil that the convergence induces. This is abundantly proved by our pupillary measurements, particularly in the older subjects. In these the extra contraction of the pupil set up by converging to the binocular (as distinguished from the monocular) near-point is quite negligible. In very young subjects with very high accommodation and extremely mobile pupils this element may be a factor and may account for the considerable discrepancy sometimes found between the monocular and binocular values.

6. On the other hand, there seems every reason to think that, in the main, the accommodative surplus in binocular vision is due directly to the convergence action itself, which, being strongly stimulated, sets up an extra accommodative effort, impossible for one who is not converging. In other words, it is a true heightening of the accommodation, not a

pseudo-accommodation, as would be the case if it were due to pupillary contraction. The difference, in fact, between monocular and binocular accommodation means that in monocular vision there is a certain degree of inertia of the accommodation which is overcome by the extra effort set up when the two eyes converge. This inertia must be seated in the ciliary muscle, *i. e.*, is an inertia of what Fuchs calls the physiologic accommodation.

7. To a certain extent the enhanced accommodation in binocular vision may be due to the added clearness, and, we may say, added realness of the binocular as opposed to the monocular image. But this surely is a subsidiary factor. That the enhancement due to the binocular act may be present without it is proved by the fact, repeatedly observed, that the binocular enhancement exists when either one eye is amblyopic so that the images cannot reinforce each other, or when there is divergent squint, so that there is no superposition of images at all, and yet still a strong attempt at convergence is made.

8. In any case the added range and clearness effected by binocular vision constitute a very real advantage, especially in presbyopia. A man who is deprived of the use of one of his eyes is quite aware that his range of near vision is considerably less and the sight itself is less satisfactory than if he had two. We must reckon with this fact in giving him a reading glass, which must, as a rule, be at least 0.5 D. stronger than if he were two-eyed.

9. Above the age of fifty-five there is a true accommodation, varying from 0.5 D. or less to 1.5 D., and averaging about 1 D. The contention is made by some that the accommodation shown at this age is spurious, being due to the small size of the pupil, which so diminishes the size of the diffusion images that the eye can see distinctly at near points without accommodating at all. This contention is negatived by our observations, which shows that often, in these elderly

subjects, the pupils are 3 mm. or more, even when converging to their reading point. Nor is the size of the pupil essentially different when the eyes are adjusted for distance and when they are focused for 25 cm., which is about the nearest point to which they are usually adjusted by glasses. We may say, then, that ordinarily distinctness of near vision is not secured by a contraction of the pupil.

In very young subjects, as we have already seen, a contraction of the pupil may possibly produce a pseudo-accommodation, but our observations lead us to suppose that this occurs but rarely.

BEARING OF OBSERVATIONS ON THE THEORY OF THE MECHANISM OF ACCOMMODATION

Accommodation is effected by a passive expansion of the elastic lens that takes place when the pressure exerted by the suspensory ligament upon the lens is relaxed. This passive expansion is aptly termed by Fuchs the physical accommodation, and the near-point to which the eye can be actually focused by the elastic expansion of the lens is called the physical near-point. Owing to the sclerosis which takes place in the lens progressively from youth on, the physical accommodation steadily diminishes and the physical near-point steadily recedes with age.

Contrasted with this purely passive expansion, which decreases from year to year, is the active contraction of the ciliary muscle, by which the relaxation of the zonula and hence the passive expansion itself are effected. This active contraction constitutes the physiologic accommodation (Fuchs), and the near-point to which the eye could be adjusted if this active contraction were pushed to its limit, and the lens also were perfectly fluid, is the physiologic near-point.

Now, while the physical accommodation diminishes steadily from youth up, it is generally held that the physiologic

accommodation does not diminish at all until advanced life. There seems no reason, indeed, why the ciliary muscle which is kept in continual practice all through life should contract any less vigorously at the age of forty-five than it does at the age of ten. In fact, both should have a physiologic accommodation of maximum amount, equivalent to a physical accommodation of not less than 20 D.

Now this inference, which is fully accepted by Hess and other exponents of the Helmholtz theory, involves certain corollaries which are not borne out by clinical evidence. For example, suppose that a man of forty-five has a maximum physical accommodation of 4 D., *i. e.*, this represents all that he can possibly do in the way of relaxing his lens. This relaxation involves a very moderate amount of effort on the part of the ciliary muscle—in fact, only a fifth of the whole 20 D. that the full activity of the latter is supposed to represent. It would seem perfectly easy for him to put forth this minimum amount of his total ciliary activity and under all conditions get 4 D. of manifest accommodation. Now, as a matter of fact, this is not the case. Tested with either eye singly, such a person rarely exerts more than 3.5 D. and often not over 3 D. of accommodation. When in this case he shows only 3 D. of physical accommodation it is evident that this also represents the total ciliary effort (physiologic accommodation) that he is making at the time; for if he made any greater effort, his physical accommodation would rise above 3 D., since the lens itself can relax up to 4 D. if the ciliary muscle contracts correspondingly. Instead, however, of uniformly showing 4 D. of accommodation under all conditions, he does so only under the extra stimulus afforded by binocular vision and convergence, and even then attains the maximum only part of the time.

The above statement holds good even up to the age (sixty or over) when the accommodation is reduced to a minimum. Thus a person of sixty who has a monocular accommodation

of only 1 D. will quite regularly have a binocular accommodation of 1.3 to 1.4 D. The extra amount of ciliary contraction required according to the ordinary theory to produce the slight additional relaxation which would be needed to effect the difference between 1 D. and 1.3 D. of lenticular refraction is so small that one does not see how anybody could fail to make it if he had a really large ciliary power to draw on. Yet evidently nearly every one does fail to make it, unless some extra stimulus like that imposed by binocular vision and the convergence of the eyes impels them to a maximum effort.

It seems inconceivable that one who really had a contractile force equivalent to 15 to 20 D. should be unable to put forth, under all conditions when called on, the comparatively small fraction required to produce a change of 2 to 4 D. in the refractive state. Far more likely does it seem that from some cause—perhaps from physiologic inhibition—the ciliary energy itself actually diminishes with the years, *i. e.*, that the physical and the physiologic accommodation diminish together, although not necessarily at the same rate.

What lends additional plausibility to this view is the behavior of the eyes under homotropin. According to the usual view, as enunciated by Hess and others, a boy of fifteen, a young man of twenty-five, and a man of forty would each have a physiologic accommodation (ciliary contraction) of equal amount, say one equivalent to a physical accommodation of 20 D. The actual physical accommodation produced by the relaxation of the lens would, on the contrary, be very different. In the first case it might be 16 D., in the second, 10 D., in the third, 5 D. In the first case there would thus be 4 D., in the second, 10 D., in the third, 15 D., of latent ciliary energy, *i. e.*, of energy which is never expended in changing the shape of the lens, and the abolition of which, therefore, would produce no effect on

the physical accommodation. If now we instil a gradually acting drug like homatropin into the eyes of all these subjects, it should begin to show an effect only after the latent energy in each case had been abolished by the paralysis. In the case of the boy, as only 4 D. are latent, the effect should be manifest very soon—in about ten minutes—after the instillation. In the second case the effect should not be manifest until quite a little later, and in the third case it should be manifest only after the lapse of thirty or forty minutes, if at all. Now, as a matter of fact, in a great many instances, at least, the cycloplegia begins to show itself almost, if not quite, as soon in the middle-aged man as it does in the boy. In fact, in persons of forty-six or forty-eight the cycloplegia due to homatropin may become manifest in from ten to fifteen minutes after the instillation and then proceeds at a rate quite like that of the youth. These facts are supported by a large number of observations in which care was taken to exclude disturbing factors, such as the blurring due to the mydriasis, etc. It would seem, therefore, that, in general, the latent ciliary energy in youth and in middle age is about the same. If this is so, then, since the manifest energy (which is measured by the physical accommodation) is very much less in middle age, the total ciliary energy, which is equal to the sum of the latent and manifest, is likewise very much less.

THE ACCOMMODATION IN MALES AND FEMALES

Examination of the great mass of statistics shows that in general the accommodation is equal in the two sexes, and that the march of presbyopia is the same in each. This is graphically shown in Fig. 5.

POST-CYCLOPLEGIC EFFECTS OF HOMATROPIN

Ordinarily the effect of homatropin, if the latter is applied in a thoroughgoing way, may be said to wear off in forty-

eight hours. But a moderate effect, noticeable by careful tests, often persists for several days later. For this reason it is best to defer a post-cycloplegic test until five or six days, at least, after the instillation.

There is, however, a more lasting effect produced by the instillation, especially in eyes with latent hyperopia. We have repeatedly noted that tests, made even some weeks after the homatropin and after the application of the correcting glasses, show an accommodation distinctly below that present before the use of the cycloplegic. It would seem as if the eye, having once learned to give up a compensating accommodative effort, could not for a time thereafter put forth even the normal accommodative power. Whether this post-cycloplegic accommodative insufficiency, which usually is never of any great amount, produces any symptoms or not I do not know.

CLINICAL APPLICATIONS

The observations recorded have an important clinical bearing. Since they establish the norms of accommodation, they afford a means of judging when and how such a given accommodation varies from the normal.

Subnormal Accommodation; Hypocyclosis.—Since the days of Donders the rôle of accommodative strain in causing the asthenopia of hyperopes and astigmatics has been a commonplace. It is all the more remarkable that, on the whole, so little attention has been paid to the part played by subnormal accommodation in causing eye troubles. Rarely, in fact, is the accommodation tested, except in a perfunctory way, and, previous to this series of investigations, there has been little if any attempt to fix the maximum and minimum limits of accommodation at each age. Yet until these latter are known we cannot, except in extreme instances, say definitely whether a given accommodation is normal or not.

It can now be positively stated that a monocular accom-

modation which is persistently below the minimum limit indicated in Table 1 is certainly subnormal, and that it is probably subnormal if it never rises much above this limit. Furthermore, the binocular accommodation should, in young persons, be at least 0.5–0.6 D., and in older subjects 0.3–0.4 D. higher than this minimum.

It does not fall within the scope of this paper to consider at length the varieties, symptoms, and treatment of subnormal accommodation. It will suffice to say that it is a frequent condition and that there are two kinds. In one, which may be called lenticular hypocyclusis, the ciliary muscle apparently acts in normal fashion, but the crystalline lens is more rigid than usual. In other words, there is a condition of premature presbyopia. In such a case there are few if any symptoms of eye-strain, but as years go on the accommodation remains persistently lower than normal, and presbyopia sets in much earlier than usual.

In the second kind of subnormal accommodation the lens has the usual rigidity, but the ciliary muscle is underactive. Except in cases due to structural disease of the central nervous system the accommodation in this variety shows wide variations from time to time, and when it is low there is often marked asthenopia. This form of low accommodation is often associated with convergence insufficiency, and the symptoms often attributed to the motor anomaly are without doubt in many cases due to the accommodative disturbance or at least are aggravated by it.

Ciliary hypocyclusis can often be relieved and the symptoms greatly helped by convergence training and by direct training of the accommodation. For the latter purpose exercise several times a day in focusing on the accommodation line, first with one eye, then with the other, and lastly with both, is useful.

Unequal Accommodation; Anisocyclosis.—Not infrequently the accommodation is found to be unequal in the two eyes.

Usually this inequality seems to be due to unequal rigidity of the crystalline lenses. It rarely causes any disturbance, but has to be reckoned with in correcting presbyopes; for if they show an unequal accommodation, it is sometimes helpful to give them also an unequal addition to the correction for distance. The fact that the accommodation may be thus unequal in the two eyes is sufficient reason for our habitually testing it in each eye separately as well as in both together.

Accommodation Measurements in Testing the Depth of Homatropin Cycloplegia.—This is an application of the accommodation tests which I regard as of great importance. The ordinary practice of making the refractive examination at a fixed time—an hour, it may be—after the first instillation of the homatropin, leaves out of consideration the fact that the march of homatropin cycloplegia varies greatly in different persons. In some few it seems complete in less than an hour; in others it is not complete for some two hours. Moreover, there seems reason to think that the acme of the effect is soon passed; at least if the test is not done until long after the instillation, the results may be uncertain.

The most satisfactory method is to make tests of the residual range at intervals, beginning an hour after the first instillation, and to defer the examination of the refraction until the range has been reduced below 1 D., then make it at once. Furthermore, when the refraction has been determined, the far-point with a + 3 D. added to the full correction should be at 33 cm. and the near-point at something over 25 cm., and preferably not less than 28 cm. (representing in the latter case a residual range of not over 0.6 D.). If these conditions are fulfilled or, still better, if, as often happens, the residual range is even less, then we can be reasonably sure that the examination has been conducted with a sufficiently satisfactory relaxation.

THE ACCOMMODATION TESTS IN OFFICE PRACTICE

The tests used require only the simplest of apparatus and can be made very quickly. They are hence adapted to the exigencies of office practice, of which, considering their importance, they should form a part in the regular routine of the examination of each case. In applying them the following precautions should be used:

1. The patient is placed in a good light and provided with his full correction and, in presbyopic cases, with such addition thereto as will bring his near-point within measurable limits. In this case, of course, the accommodation read off on the scale must be diminished by the strength of this added glass.

2. In very young subjects with high accommodation (12 D. or more) it is often well to add a -3 or -4 D. to the distance correction in order to carry the near-point out to a place on the rule where, the graduations bearing further apart, there will be less likelihood of error in the measurement. Of course, in this case the accommodation as read off on the scale must be increased by the strength of this added glass.

3. The zero point of the Prince's rule is placed 14 mm. in front of the cornea (practically in the plane of the patient's correcting glass).

4. The left eye is covered, and the accommodation card carried in along the rule until the line seen with the right eye blurs or doubles. The corresponding value of the accommodation is then read off in diopters. Then the right eye is covered and a similar test made with the left, and lastly the accommodation is measured with both eyes open, the patient at the same time being urged to converge on the test-object.

5. It is well to make sure that the patient understands exactly what we desire him to observe and to make several observations in succession in order that we may get his maximum effort.

SUMMARY

1. The examination of the accommodation in 4200 eyes enables us to state with precision the maximum and minimum limits, as well as the mean values of the monocular accommodation at all ages. The results obtained are shown in the curves and tabular values here presented.

2. These observations substantially confirm those made ten years ago. The mean and lower limits have been set somewhat lower, so as to be sure not to exclude any low normal cases. Any case whose accommodation is persistently below the minimum limit is certainly subnormal, and any case in which the accommodation remains only slightly above the minimum limit is probably so.

3. The binocular accommodation is regularly higher than the monocular, the excess being regularly equal to 0.6 D. or more below the age of 17; 0.5 D. from 18 to 31; 0.4 D. from 32 to 53; and 0.3 D. for ages over fifty-three. In individual cases the difference may be much greater.

4. This difference is a very real advantage, especially in presbyopes. Binocular accommodation is not only higher, but better as regards ease and clearness. This fact must be borne in mind especially in prescribing reading glasses, and in cases of monocular vision (monocular cataract, etc.), usually we must prescribe a glass 0.5 D. or so stronger than we would for a two-eyed patient.

5. The excess of binocular accommodation apparently represents an actual increase of ciliary effort imposed doubtless by the act of convergence. It cannot be attributed to the added clearness secured by a contraction of the pupils, since it is quite uniformly observed, even when no such contraction exists.

6. As little can the contraction of the pupil be called in to account for the accommodation of 1 D. or more quite regularly observed in patients over fifty-five. The accommodation in this case in all probability represents the same process

as in youth—*i. e.*, relaxation of the lens produced by contraction of the ciliary muscle.

7. These observations and others adduced should lead us to modify somewhat our conceptions of the accommodative process. Particularly these should lead us to think, contrary to the prevalent view, that not only the elasticity of the lens (physical accommodation), but the activity of the ciliary muscle (physiologic accommodation), diminishes with age, and that in advanced life only a comparatively small amount of ciliary energy can be put into play.

8. The accommodation is equal, and presbyopia advances at the same rate in the two sexes.

9. The relaxation of effort produced by homatropin and by the prescribing of correcting glasses seems in many cases to set up a condition of moderate accommodative insufficiency, lasting, it may be, for a number of weeks.

10. The practical applications of these observations are of considerable importance. In particular, the observations determine whether a given accommodation is subnormal or suspiciously low, and enable us to tell when we have succeeded in raising it to near the normal limit. Subnormal accommodation is frequent and comprises two kinds—lenticular and ciliary. The former, which may be called a premature presbyopia, is a stable condition, causing apparently little or no reflex symptoms; the latter is a variable condition, often causing marked asthenopia and requiring active treatment. The other practical applications consist, first, in the recognition of the fact that the accommodation may be unequal in the two eyes, so that in presbyopia an unequal reading addition may be required; and, second, in the employment of the accommodation tests in determining the depth and reliability of homatropin cycloplegia.

11. In order to make the tests available for practical application they should be performed in a uniform way and with certain precautions. When so performed, they

give reliable results. They are readily and briefly made with simple apparatus, and hence are easily adapted to the conditions of ordinary office work.

DISCUSSION

DR. C. D. WESCOTT, Chicago: Since reading Dr. Duane's paper of about twelve years ago, and to which he has referred, I have made it a practice in daily routine work to test the accommodation of every patient I refract. I am able to confirm many of the theoretic observations that Dr. Duane has mentioned, and I wish the time were not so short that I might go into the matter more in detail. But I want to urge upon you the importance of testing the monocular accommodation in all presbyopes. I have been able to relieve a great many patients suffering from asthenopia by discovering the difference in the accommodation of the two eyes and equalizing it. Patients who had not had comfort in the use of their eyes before have been made perfectly comfortable.

DR. J. F. SHOEMAKER, St. Louis, Mo.: For some years I have noted a marked variation in the amount of accommodation from what we might consider the average, both in young people and in those who have reached what is generally supposed to be the presbyopic age. I have not, however, tabulated my findings.

In connection with Dr. Duane's paper I wish to refer briefly to three cases I have had under observation that show a decided variation from the average accommodation. The first is a healthy lad of twelve years, who under homatropin cycloplegia showed 1.25 diopters of hypermetropia. In the post-cycloplegic test he read 18/15 plus with each eye, with his full correction, but the best he could do at reading was Jaeger 1 at eight inches, with a + 1.00 added to this. With full distance correction he was not comfortable when reading, but with an additional reading glass he is entirely comfortable and has gotten along nicely.

The second case is a young woman, thirty-two years of age. Under homatropin cycloplegia she showed 5.00 diopters of hypermetropia and a little astigmatism. After the effect of the cycloplegic had worn off, with full correction she could read Jaeger 1 at nine to ten inches only, whereas we expect patients at this age to read it at four or five inches.

In contrast to these two cases, the third case was a man fifty-four years of age, who has only one eye. He has 2.00 diopters of

hypermetropic astigmatism, reads comfortably for hours with his distance correction, and is able to read Jaeger 1 at ten inches very plainly. It shows the great variation in accommodative power, both in youth and in middle age.

DR. EDWARD JACKSON, Denver, Colo.: Dr. Duane has referred to the obvious practical importance of knowing the minimum limit of accommodation. It is worth while to call attention to the fact that after middle age it is also of great practical importance to have an understanding of the maximum limits of accommodation. I think that through the supposition that accommodation is entirely, or has become, negligible through its diminution there has very often been a failure to recognize the accommodation present, and also failure to recognize the hyperopia concealed by the accommodation present. I am sure I have had cases in which the maximum accommodation after fifty years of age came up to these figures given in Dr. Duane's paper, much higher than are usually indicated in our text-books or that have been reported by previous observers.

My attention was first called to the frequency of such cases some seventeen years ago, when I came to review about 4,000 eyes. I published the results in individual cases, not tabulated results. I can recall a case repeatedly and very carefully tested that showed three-quarter diopter accommodation at eighty years of age. All possible sources of error I think were excluded in that case and the man was repeatedly tested.

There was one apparent fact brought out by my statistics that is contradicted by Dr. Duane, and I think probably Dr. Duane's statistics are more carefully prepared than mine, and which I tried to verify and did support by the careful observation of quite a number of patients whose ages I was certain of. That was, that in women I found the error of accommodation, even aside from any possible misinformation as to age, seemed to be distinctly lower at the same age than in men. That at least the proportion was not equal. Whether it was the lessened power of the ciliary muscle, or a lessened tendency to exert neuromuscular power, I could not say, but certainly my figures seem to show that the accommodation was slightly lower on the average in women than in men.

DR. A. DUANE, New York City: I have nothing to add except with reference to Dr. Jackson's statement. It did seem to me, after multiplying observations on 500 cases, that it was idle to go

further, because while the variation in accommodation was very great in individual males or females, yet the average of the two sexes was about the same. Sometimes the male accommodation was higher, sometimes the female, but on the whole, one was about as good as the other. If you look at the chart, you will see the red and black are pretty well mixed, so we could not say definitely that the red was higher or that the black was higher.

SIMPLE METHODS OF ORTHOPTIC TRAINING

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Exercises to modify and perfect the ocular movements should be given with simple apparatus; since they are to be performed often by very young children, and sometimes under the supervision of parents untrained in ophthalmology, or the care or manipulation of mechanical instruments. Such exercises should also have a wide range of variation, both to provide for the exercise of many different movements and coordinations of movement, and to avoid monotony that impairs interest and leads to perfunctory carrying out of a routine that brings no benefit.

To be most effective, the apparatus should be capable of shifting the direction of the rays falling on the eye, through every intermediate position, without any interruption of the process. Those who have worked with the rotary prism realize how much more satisfactory it is, giving a continuous change of effect, than prisms of different strengths substituted one for another, with a break in the exercise at every change of prism; even though these prisms be arranged in convenient form in a battery, which permits going directly from one prism to the next.

The two forms of orthoptic apparatus here discussed have these advantages: they are relatively simple, and they give