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**CRITICAL VALUES FOR THE LIGHT MINIMUM
AND FOR THE AMOUNT AND RAPIDITY
OF DARK ADAPTATION**

BY

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THE retinal functions usually selected for the study and diagnosis of eye diseases are the light and colour sense as tested by the determination of the minimal and difference thresholds in central vision and with the perimeter and tangent screen in peripheral vision. There are other functions, however, which may also be worthy of consideration in this connection. A very important function is the changing sensitivity of the retina as a reaction to intensity of light. In the maturity and versatility of this reaction the eye is unique.

When the photographic plate is acted upon by light there is a very rapid and a permanent loss of sensitivity. When the retina is acted upon by light there is also a rapid loss of sensitivity, but the loss is much less rapid than for the photographic plate and is not permanent. When the light is shut off, the retina completely

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recovers its sensitivity unless damaging intensities have been used; but the rate of recovery is much slower than the rate of loss. Furthermore, any change in the intensity of light to which the eye is exposed is followed by an increase or decrease in sensitivity, depending upon the direction in which the change takes place. This capacity to change its sensitivity in reaction to intensity of light serves a very important purpose in the economy of vision. The sensorium functions effectively only within a certain range of intensity of excitation. When the intensity is too high, dazzle or glare results and the details in the image are confused; and when it is too low, the sensation difference between the details in the image becomes too slight to be discriminated. This adaptive function or capacity to change its sensitivity tends, therefore, to keep the retina functioning within the favourable range of excitation.

Other aspects of the excitation of the sensorium and the change in its excitability due to exposure to light are contrast and after-image. By contrast, brightness difference and certain colour differences between details in the image are accentuated in sensation. This is, of course, an important aid to their discrimination. Further, it is an important aspect of this aid that both brightness and colour contrast are increased at low illumination where the physical conditions for visibility are poor, and that colour contrast is the greatest when there is little or no brightness difference in the details of the image to serve as a basis for their discrimination.

As their name indicates, after-images of themselves play no part in the sensory picture produced by the physical image on the retina. The positive after-image, which is of very short duration with a light-adapted eye, renders an important service, however, in giving smoothness and continuity to the visual experience of successive impressions without causing a confusing and troublesome overlapping of the impressions, and perhaps reduces the time of exposure that is required for their discrimination. Another important factor in the smoothness and continuity of the visual experience is the lag in the response of the retina. That is, if sensation rose to its full value immediately on receiving the impression and died away abruptly at the cessation of the stimulation, the visual experience would be disconnected and discontinuous as the eyes shift their fixation quickly from one object to another or when for any reason visual impressions succeed each other at short intervals.

The negative after-image, coming at a later stage in the reaction and only under certain conditions of observation, is of no use at all in the act of seeing. However, it has its origin in the processes underlying the changes in sensitivity which occur as a reaction to intensity of light and is of value in experimental work and in

testing, as an index of the stage of recovery of sensitivity after the light is shut off.

It is scarcely conceivable that these more delicate and in some cases more complicated functions of the sensorium are not affected by pathological disturbances. They and other aspects of the visual response, such as the fusion of colours and of brightness and colour, the reaction to successive impressions at different rates of succession, etc., offer interesting possibilities for study in relation to diseases of the eye. Whether they can be made of service in diagnosis, however, remains yet to be determined. Success in this respect depends in very large measure on the methods that are devised for the control of the variable factors which influence the results, on the instruments which are used for applying these methods and on the predetermination of correct and suitable critical values to serve as a basis for detecting pathological disturbances and for differentiating between diseases. In carrying out our programme for the study of the diseases of the eye it is our intention to include as many of these functions as may be found to be feasible and of value for the purpose.

Of these, the processes involved in the change in sensitivity with change of intensity of light would seem to be the most obviously fundamental and important. Also their apparent similarity to the bodily processes of fatigue and recovery suggests that they may have great susceptibility to pathological disturbances. It has been our purpose in the present study to consider in relation to the light sense the slower of these two processes and, for that reason, the one more feasible for testing, namely, the changes in the sensitivity to light which occur during dark adaptation. This study has involved the determination of the light minimum immediately after a suitable length of exposure to light of a given intensity and at selected intervals after the light was shut off through a period of 20 minutes. The results of these determinations plotted in a curve present a very comprehensive picture of the power of the retina to recover from the loss of sensitivity produced by stimulation by light. Such a picture portraying not only the eye's place or ranking in a scale of sensitivities, but also its power or capacity to recover its sensitivity after fatigue, should certainly give us at a glance important information as to its health and general state of efficiency, so far as reaction to stimulation by light is concerned. The items shown in the curves are the range or total amount of recovery, the amount which occurs in each of the intervals tested, and the rapidity of recovery for each of these intervals and for the total time. The grading or ranking of a given eye with reference to these particulars obviously requires a scale, or other means showing graded distribution, in which the range and frequency of occurrence of the various levels of sensitivity and

powers of recovery are shown for a suitably sampled group of non-pathological eyes. Provided with such a scale it should not be difficult for the examiner to reach a reasonably satisfactory conclusion as to the normality of the light sense for any eye examined.

In the following paper will be given tabular results for 206 carefully selected non-pathological eyes; distribution curves which show the frequency of occurrence of the various values of light minimum at the end of the period of light adaptation and after 20 minutes of dark adaptation; curves plotted at significant points in the distribution of cases, which show the rapidity of change of the light minimum during the intervals selected for making the determinations; and as a special aid in making a diagnosis or classification, a chart which shows the median, the 95 and the 5 percentile curves. The place of these curves in the entire group may be indicated as follows: 50 per cent. of the cases gave values of light minimum equal to or better than those represented in the median curve and 50 per cent. equal to or worse; 5 per cent. gave values equal to or worse than those shown in the curve selected to represent the upper normal limit; and 5 per cent. gave values equal to or better than those shown in the curve selected to represent the lower normal limit. The 5 percentile curve (called in the chart the upper normal limit) has been chosen by us as representing values of the light minimum and course of adaptation which may be considered as suspicious or borderline between healthy and pathological eyes. By drawing the curves for any given eye on this standard chart, its relationship to the selected group of normal eyes may be readily seen. We have found these charts to be of very great value in the detection of pathological disturbances, especially in borderline and near-borderline cases when the help is most needed, and in evaluating small changes in the advance and recession of such disturbances in many ocular diseases.

Method of Working

The determinations were made with the Ferree-Rand instrument for testing the light sense and the amount and rapidity of light and dark adaptation. This instrument was devised for the control of all the factors which influence the results of the test for sensitivity to light and for making a specification by direct measurement of the amount of light entering the eye in any determination. It has been described and its features and advantages enumerated in a previous paper.*

* Ferree, C. E., Rand, G — A new type of instrument for testing the light and colour sense. *Amer. Jl. Ophthal.*, Vol. XIV, p. 325-333, 1931.

The instrument made it possible to do the work under the precise conditions of measurement and control that are needed in making standard determinations. Some of these were: (1) All variable effects due to size of pupil, accommodation, distance of projection of the image and errors of refraction were, as far as is possible, eliminated from the results; (2) the eye was pre-sensitized to a constant state of light adaptation before each series of determinations was begun; (3) determinations of the light minimum were made with a constant degree of light adaptation and after fixed intervals of dark adaptation; (4) fixation was maintained in all cases with a very satisfactory degree of accuracy; (5) the density of light or the amount entering the eye per unit area of stimulus was measured directly and expressed in terms of lumens $\times 10^{-10}$ per sq. mm. of stimulus; and (6) a means of making an objective check on the judgment was provided.

After considerable preliminary experimentation on the effect of size and shape of stimulus on the results, an oblong stimulus subtending a visual angle of 10 degrees in the horizontal dimension and 3 degrees in the vertical was chosen as the most suitable for making the standard determinations. As an objective check on the judgment this stimulus could be rotated when desired into any position within a range of 180 degrees.

As an aid to the control of fixation, the test was always begun at an intensity at which the stimulus was visible and the observer was instructed to look at its centre. The light was then rapidly decreased until it was reported as no longer seen and then again increased to the threshold of visibility. Little or no difficulty was experienced in the control of fixation for a stimulus of this size as its edges extended into the more sensitive peripheral retina and there was in consequence no incentive for the eye to take an eccentric fixation, *i.e.*, the stimulus was most clearly seen when its centre was fixated. It can be readily understood that the use of any luminous device within the stimulus area for the control of fixation, however low the luminosity, would not have been desirable because of the effect it would have had on the value of the light minimum. It can be further understood that circumscribed devices such as we have described in a former paper* would not be effective with the size and shape of stimulus which we have found best to use in making these determinations; and that the blind spot control which we also described in that and other papers is entirely infeasible for any type of clinical work. With the size of stimulus and the method used in making the determination a very satisfactory reproducibility of result was obtained

* Ferree, C. E., Rand, G. and Stoll, M. R.—Size of stimulus in relation to the eye's sensitivity to light and to the amount and rate of dark adaptation. *Jl. Exper. Psychol.*, Vol. XVII, pp. 646-661.

for any given observer and a sufficiently narrow range of scatter in the group of observers. This is commonly accepted as the final and practical check on adequacy of control.

In order that each series of determinations should be begun with the eye in as nearly the same state of sensitivity as possible, the observer was adapted for 20 minutes in a lighted room before the test was begun. The walls and ceiling of the room were of rough plaster painted flat white. The room was illuminated by a centrally located ceiling fixture of the indirect type, specially designed to be completely glareless. To secure a higher illumination near the position of the observer than was given by the ceiling fixture, a floor lamp was used in addition, designed also to be completely free from glare. The horizontal component of illumination at the position of the observer was 16 ft.-c.; the component normal to the reading page 11 ft.-c. At the end of this period the observer was seated in position in front of the instrument. To compensate for inequalities in the time which this allowed for recovery of the eye at different sittings and further to complete and standardize the pre-sensitization of the eye, the test was begun by requiring the observer to look for three minutes into the illuminated pre-exposure field of the instrument. This field is circular in shape and subtends an angle of 36 degrees at the eye. The density of light in the field was 17×10^{-8} lumens per sq. mm. This value is approximately 550 times the average value of the light minimum for all the observers in the group at the beginning of the period of adaptation and 447,000 times that value after 20 minutes of dark adaptation. At the end of the pre-exposure period, the plate containing the stimulus aperture was dropped into position and the light reduced to threshold intensity as quickly as possible by the interposition of a neutral filter of the proper density and the rapid adjustment of the distance of the lamp of the instrument until the observer reported the disappearance of the stimulus. The light was then quickly increased until the stimulus reappeared and the point of reappearance was taken as the light minimum.

The light minimum was determined in this way at the end of the three minute pre-exposure period and at selected intervals thereafter until little or no change in sensitivity could be detected. The intervals used were 1, 2, 5, 10, 15 and 20 minutes. There was, of course, some slight variation in the time consumed in arriving at the final determination, but in general this time was no longer than three seconds. As might be expected, the data for the first point of the curve were found to be more variable than for the others, due to the fact that the exact time at which

the determination is completed exerts a greater influence on the results obtained at the beginning of the period of adaptation when the rate of change of sensitivity is at its maximum. In conducting the test, care was taken to reduce this variability to a minimum. The type of test instrument used was of great aid in this respect.

Two hundred and six eyes were tested, 114 of males and 92 of females. The persons examined included private patients, students, nurses, assistants on the hospital staff, hospital employees and a large number of clinic patients. In every case the refractive condition of the eye was carefully determined and an ophthalmoscopic examination made. No cases showing a pathological condition, however slight, were included in the group. The 206 cases ranged in age from 9 to 70 years. Ten fell in the group 5 to 15 years; 40 in the group 15 to 25 years; 64 in the group 25 to 35 years; 47 in the group 35 to 45 years; 36 in the group 45 to 55 years; 5 in the group 55 to 65 years; and 4 in the group 65 to 75 years. It was very difficult to obtain observers over 55 years of age who could be classed as completely normal in the ophthalmoscopic examination. Cases, for example, having arteriosclerosis, slight lenticular opacities and cloudiness of the media were not accepted. Because of the few cases in of the groups 55 to 65 years and 65 to 75 years, they were combined in the statistical treatment of the results.

Results

Early in the work it was realized that the older subjects tended to have higher light sense thresholds than the younger at all periods of adaptation and that, therefore, age would have to be taken into account in establishing borderline or critical values for clinic use. To determine the effect of age, the average and median values of light minimum were computed for each decade group at the end of the period of light adaptation and after 1, 2, 5, 10, 15 and 20 minutes of dark adaptation. These values are given in Table I. From this table it is seen that there is a fairly consistent increase in the light minimum with age. The trend is shown most clearly for the longer periods of adaptation. This is due to the fact that the slower change in sensitivity at these periods makes it possible to obtain more exact measurements of the light minimum. Two reasons may be cited for this. (a) Check determinations can be made at these points and (b) variations in the exact time at which the final judgment is reached constitutes a less important factor in the results obtained.

TABLE I.

The average and median values of the light minimum in lumens $\times 10^{-10}$ entering the eye per sq. mm. of stimulus at the end of the period of light adaptation and after 1, 2, 5, 10, 15 and 20 minutes of dark adaptation for the decade groups from 5 to 75 years. 206 non-pathological observers, ages 9 to 70 years.

Interval of Adaptation →		0 min.		1 min.		2 min.		5 min.	
Age Group	Number of cases	Average	Median	Average	Median	Average	Median	Average	Median
5-15	10	2.83	2.44	0.240	0.203	0.073	0.060	0.0160	0.0133
15-25	40	2.32	2.21	0.195	0.187	0.050	0.038	0.0171	0.0161
25-35	64	3.16	2.36	0.274	0.221	0.065	0.054	0.0212	0.0161
35-45	47	3.34	2.41	0.317	0.263	0.073	0.080	0.0264	0.0209
45-55	36	3.84	2.72	0.232	0.221	0.083	0.071	0.0267	0.0221
55-75	9	3.59	2.21	0.346	0.263	0.097	0.069	0.0272	0.0197

Interval of Adaptation →		10 min.		15 min.		20 min.	
Age Group	Number of cases	Average	Median	Average	Median	Average	Median
5-15	10	0.0079	0.0065	0.0044	0.0042	0.0029	0.0017
15-25	40	0.0083	0.0077	0.0048	0.0039	0.0032	0.0027
25-35	64	0.0086	0.0072	0.0048	0.0037	0.0033	0.0030
35-45	47	0.0104	0.0119	0.0064	0.0064	0.0040	0.0037
45-55	36	0.0124	0.0102	0.0078	0.0073	0.0048	0.0044
55-75	9	0.0121	0.0112	0.0079	0.0076	0.0054	0.0044

For the purpose of determining norms for clinical use, it was decided to divide the observers into two groups—those below and those above 35 years of age. The following reasons may be given in justification of this decision. (a) Two sets of standards, one for cases below and one for cases above 35 years of age, are not too cumbersome to handle; and (b) particularly for the more reliable values (those obtained after five minutes of dark adaptation) there seems to be a rather clear differentiation between the average thresholds of the decade groups above and below 35 years of age.

For the more general statistical treatment of the results, however, the observers were considered in three groups: Cases under 35 years of age ($N=114$), cases over 35 years of age ($N=92$) and the total group ($N=206$). Results for these groups are given in Table II and Fig. 1. In the table are shown for the three groups the average and median values of the light minimum at each period of adaptation tested; the limiting values of light minimum for the total number of cases, for the middle 90 per cent. of cases and the middle 50 per cent.; and, as an index of the scatter of

TABLE II.

The light minimum in lumens $\times 10^{-10}$ entering the eye per sq. mm. of stimulus at the end of the period of light adaptation and after 1, 2, 5, 10, 15 and 20 minutes of dark adaptation for the age groups below and above 35 years and for the total group: (a) the average values; (b) the median values; (c) the limiting values; (d) the limiting values of the middle 90 per cent. and the middle 50 per cent. of cases examined; (e) the median deviation expressed in 1×10^{-10} lumen; and (f) the median deviations expressed in per cent. of the median values. 206 non-pathological observers, ages 9 to 70 years.

AGE GROUP	Interval of Adaptation	Average Light Minimum 1×10^{-10} Lumen	Median Light Minimum 1×10^{-10} Lumen	LIMITING VALUES. 1×10^{-10} LUMEN			MEDIAN DEVIATION	
				Total Number of Cases	Middle 90 per cent. of Cases	Middle 50 per cent. of Cases	1×10^{-10} Lumen	Per cent.
Below 35 Years	0 min.	2'84	2'36	0'04 - 11'23	0'51 - 7'53	1'36 - 3'65	1.15	48.7
	1 "	0'244	0'209	0'006 - 1'120	0'053 - 0'630	0'128 - 0'280	0'076	36.3
	2 "	0'0617	0'0543	0'0056 - 0'3138	0'0122 - 0'1445	0'0248 - 0'0866	0'0310	57.1
	5 "	0'0193	0'0161	0'0026 - 0'0937	0'0053 - 0'0475	0'0112 - 0'0227	0'0058	36.0
	10 "	0'0084	0'0076	0'0012 - 0'0236	0'0025 - 0'0176	0'0047 - 0'0117	0'0035	46.1
	15 "	0'0047	0'0037	0'0009 - 0'0146	0'0014 - 0'0102	0'0029 - 0'0058	0'0015	40.5
	20 "	0'0032	0'0028	0'0007 - 0'0092	0'0010 - 0'0071	0'0019 - 0'0043	0'0012	42.9
Above 35 Years	0 "	3'53	2'46	0'47 - 14'45	0'88 - 9'67	1'84 - 4'41	1.29	52.4
	1 "	0'297	0'236	0'050 - 1'445	0'059 - 0'800	0'133 - 0'340	0'104	44.0
	2 "	0'0785	0'0701	0'0131 - 0'3000	0'0209 - 0'1590	0'0382 - 0'1102	0'0359	51.2
	5 "	0'0264	0'0209	0'0051 - 0'0870	0'0075 - 0'0663	0'0133 - 0'0310	0'0089	42.5
	10 "	0'0120	0'0112	0'0026 - 0'0445	0'0043 - 0'0263	0'0068 - 0'0136	0'0034	30.4
	15 "	0'0070	0'0068	0'0014 - 0'0236	0'0025 - 0'0128	0'0044 - 0'0092	0'0025	36.8
	20 "	0'0044	0'0041	0'0010 - 0'0121	0'0014 - 0'0099	0'0031 - 0'0052	0'0011	26.8
Total Group	0 "	3'13	2'38	0'04 - 14'45	0'54 - 8'67	1'48 - 3'90	1.21	50.8
	1 "	0'267	0'221	0'006 - 1'445	0'057 - 0'747	0'130 - 0'300	0'085	38.4
	2 "	0'0692	0'0612	0'0056 - 0'3138	0'0136 - 0'1447	0'0306 - 0'1000	0'0347	51.7
	5 "	0'0224	0'0176	0'0026 - 0'0937	0'0067 - 0'0614	0'0128 - 0'0246	0'0059	33.5
	10 "	0'0100	0'0092	0'0012 - 0'0445	0'0029 - 0'0197	0'0052 - 0'0130	0'0039	42.4
	15 "	0'0057	0'0048	0'0009 - 0'0236	0'0015 - 0'0110	0'0034 - 0'0078	0'0022	45.8
	20 "	0'0038	0'0034	0'0007 - 0'0121	0'0011 - 0'0078	0'0024 - 0'0049	0'0013	38.2

results, the median deviations expressed both in lumens and in per cent. of the medians.

In Fig. 1A are given the adaptation curves derived from the 50 percentile or median value at each period tested for the group below 35 years of age, from the 25 percentile or first quartile value, from the 75 percentile or the third quartile value and from the 95 and 5 percentile values; in Fig. 1B, curves for these values are

FIG. 1.

The light minimum for 206 non-pathological observers, ages 9-70 years, at the end of the period of light adaptation and after 1, 2, 5, 10, 15 and 20 minutes of dark adaptation for the 5, 25, 50, 75 and 95 percentile cases: (A) for the total group; (B) for the group below 35 years of age; (C) for the group above 35 years of age. The light minimum is expressed in lumens $\times 10^{-10}$ entering the eye per sq. mm. of stimulus.

given for the group above 35 years of age; and in Fig. 1c, for the total group. The distance between the two limiting curves represents the middle 90 per cent. range of values; that between the second and fourth curves, the middle 50 per cent.

In Fig. 2 are given distribution curves of the results for the total number of cases at the end of the period of light adaptation and after 20 minutes of dark adaptation. Both of these curves

show that the values of the light minimum are not distributed normally in an unselected group of observers, but cluster at the lower end of the scale of values of light minimum, or at the upper end of the scale of sensitivities. In this we have conformity with the skewed type of distribution which is frequently found in measurements of simple sensory response, reaction time, speed of

FIG. 2.

The distribution of the light minimum for 206 non-pathological observers, ages 9-70 years: (A) at the end of the period of light adaptation and (B) after 20 minutes of dark adaptation. The light minimum is expressed in lumens entering the eye per sq. mm. of stimulus.

response, etc. That is, a large percentage of cases give values which fall within the upper half of the range of power of performance and a small percentage, values which fall within the lower half. For example, in the present case the range of light minimum for the total number of observers at the end of the period of light adaptation is from 1-145 lumens $\times 10^{-11}$. In the lower half of this range fall 179 or 87 per cent. of the total number of cases; and in the upper half, 27 or 13 per cent. The range of

light minimum after 20 minutes of dark adaptation is from 7–121 lumens $\times 10^{-14}$. In the lower half of this range fall 176 or 85 per cent. of the total number of cases; and in the upper half, 30 or 15 per cent.

It might be regarded as interesting and important to treat individual differences in the amount and rapidity of dark adaptation numerically and statistically, as well as individual differences

FIG. 3.

Record sheets on which the results for each new case examined may be plotted and compared with standard curves, representing the results for 206 non-pathological observers, ages 9-70 years.

in the light minimum. The importance of such treatment, however, is much less than it might seem to be because of the very great magnitude of the difference between the minimum before and after the period of dark adaptation—of the order of 1 to 1,000. In any comparison that might be made, therefore, the relationships from individual to individual will be very similar to those obtained for the values of the light minimum before the period of dark adaptation, too similar to justify the space that would be required for their presentation here. A sufficiently good conception of the individual differences in both of these respects can be had by

inspecting the shape of the adaptation curves, given in Fig. 1, which have been plotted at significant points in the distribution of cases.

For clinical application of the data on the light minimum, it was decided to select as borderline or critical the 5 percentile value at each period tested in the course of dark adaptation. The exclusion of the extreme 5 per cent. of high values of light minimum was thought to be justifiable in order to eliminate the influence of

FIG. 4.

Record sheets on which are plotted the results for several pathological cases for comparison with standard curves representing the results for 206 non-pathological observers, ages 9-70 years.

chance observations, erratic judgments, fatigue, values affected unduly by the "streaming" phenomena which occur during prolonged periods in the dark, momentary fluctuations in the control of the physical conditions of experimentation, etc. These borderline values are shown in the upper curves of the record sheets reproduced in Fig. 3.

At A is shown the record sheet used for the younger age group, and at B that for the older group. In order better to aid in the orientation of any new case examined in relation to a suitably sampled group of non-pathological subjects, the median or middle

adaptation curve is also represented and the curve for the 95 percentile case, called in the chart the lower normal limit of the light minimum. When the curve for such a case has been plotted on the record sheet, inspection shows immediately whether it falls within or outside the normal limits, and whether above or below the median. Further, these items of information are readily obtainable for the early, middle or late periods in the course of adaptation.

For convenience of judging and preserving the results obtained in clinical testing, they should for each case examined be plotted in the form of a curve on the record sheet or standard chart noted above. When the Ferree-Rand instrument is made available to the medical profession these charts will be supplied with the instrument. Their use as record sheets is shown in Fig. 4. In this figure, in order to save space, the curves for several pathological cases which show a reduced light sense are plotted on one chart. These curves were taken at random from our files and since they are presented only to illustrate the use of the record charts and not to represent results which may be regarded as typical in various pathological conditions, the diagnoses are not given. In later papers we hope to give data which will fairly represent the effect of the various ocular diseases on the light sense and on dark and light adaptation.

The data given in Figs. 1 and 2, and Tables I, II and III may be further summarized as follows: (1) The average values of the minimum at the end of the period of light adaptation and after 1, 2, 5, 10, 15 and 20 minutes of dark adaptation are respectively 3.13, 0.267, 0.0692, 0.0224, 0.010, 0.0057 and 0.0038 lumens $\times 10^{-10}$ entering the eye per sq. mm. of stimulus. (2) The average value of the minimum before dark adaptation is 824 times that of the minimum after 20 minutes of dark adaptation, *i.e.*, on the average the sensitivity of the eye after 20 minutes of dark adaptation is 824 times as great as when adapted to light of the intensity used for the pre-sensitization period in this study. (3) The gain in sensitivity for the first two minutes was 4,429 per cent.; for the first five minutes, 13,893 per cent.; for the second five minutes, 124 per cent.; for the third five minutes, 75 per cent.; and for the fourth five minutes, 50 per cent. (4) The critical values for the light minimum at the end of the period of light adaptation and after 1, 2, 5, 10, 15 and 20 minutes of dark adaptation are respectively for the group under 35 years of age 7.53, 0.630, 0.1445, 0.0475, 0.0176, 0.0102 and 0.0071 lumens $\times 10^{-10}$ entering the eye per sq. mm. of stimulus; and for the group over 35 years of age 9.67, 0.80, 0.159, 0.0663, 0.0263, 0.0128 and 0.0099 lumens $\times 10^{-10}$.

In a later paper age, sex, condition of refraction and pigmentation as factors in the sensitivity to light and its change with dark

adaptation will be discussed. While sex, condition of refraction and pigmentation are factors, their influence is not of sufficient importance to require that they be taken into account in diagnosis.

Summary

In the foregoing paper the light sense and the amount and rapidity of dark adaptation are studied in relation to the needs and requirements in clinical work. Values are given for the light minimum on 206 eyes at ages ranging from 9 to 70 years, 114 male and 92 female. Determinations were made at the end of a standardized period of light adaptation and after 1, 2, 5, 10, 15 and 20 minutes of dark adaptation. Curves were plotted to show the distribution and range of scatter of the results obtained and a brief statistical treatment is given to bring out points of interest and value in diagnosis.

For the purpose of determining norms for clinical use the observers were divided into two groups—those under and those over 35 years of age. The 5 percentile values were selected as critical or borderline, and were plotted in the form of a curve to be used as a standard in the examination of new cases. Two record sheets are shown, one for each of the age groups, on which this curve was plotted and in addition two other curves, representing respectively the median and the 95 percentile values, in order better to aid in the orientation of the results of any new case examined in relation to those obtained from a group of non-pathological cases. These record sheets should be supplied with the instrument used for making the test.

PRIMARY GLAUCOMA

The Respective Values of the Different Forms of Treatment of this Disease

BY

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THIS disease, primary glaucoma, as we know, is the subject of much debate as to its cause and as to the most effective manner of treatment.

With your permission I shall divide this disease into two kinds, *viz.*, that which is associated with non-cupping of the optic disc, and that form which has cupping of the optic disc.