MEDICAL EVALUATION OF NUTRITIONAL STATUS[1]

VI. DARK ADAPTATION OF HIGH SCHOOL CHILDREN AT DIFFERENT INCOME LEVELS

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INTRODUCTION

DARK adaptation measurements have been widely used to detect night blindness which may be an ocular expression of an avitaminosis A. The term, night blindness, means impaired vision under dim illumination. Its sign is a relative visual failure evidenced by an elevated threshold at light intensities which although low are within the normal range of human visibility.

A variety of factors has been found to alter visual sensitivity. Threshold elevation accompanying lack of vitamin A in the diet or its faulty utilization has been found experimentally in a number of subjects (31, 9, 10, 2, 1). Stewart reported reduction of threshold level by vitamin C therapy (29). Visual sensitivity is reduced by depression of the oxidative process in the central nervous system in anoxia and hypoglycemia (18). Elevated threshold may result also from hereditary abnormality of the retinal rods and ocular pathologies such as opacities of the cornea and lens and lesions of the retina, choroid, and optic nerve (16).

Night blindness due to lack of vitamin A appears to be correlated not only with intraretinal changes but also with changes in the intermediary and central parts of the visual apparatus and central nervous system. Fridericia and Holm (6), Tansley (30), and many later investigators have stressed the association of night blindness during avitaminosis A with reduced regeneration of photo-

[1] This paper is the sixth of a series from a cooperative investigation by the Milbank Memorial Fund; the New York City Department of Health; the United States Public Health Service, Division of Public Health Methods; and the Cornell University Medical College, Department of Public Health and Preventive Medicine and Department of Pediatrics.

The cooperating agencies have been assisted in carrying out this investigation by the Work Projects Administration for the City of New York, Official Project No. 65-1-97-21 W. P. 24, "Medical Evaluation of Nutritional Status."

sensitive pigment in the retina. Recently Moore and Sykes (21), have described the correlation of cerebrospinal fluid pressure with night blindness and papilloedema in calves on a vitamin A deficient diet. Night blindness followed by papilloedema was preceded by an increase in cerebrospinal fluid pressure. Richards and Irving (25) reported very early lesions due to vitamin A deficiency in the optic tract and medulla in rats which were gaining in weight and showed no outward signs of avitaminosis A. It appears from these reports and others that night blindness in avitaminosis A cannot be entirely explained on the basis of photochemistry of the receptor cells and that a broader interpretation is required which takes cognizance of correlated events in extraretinal parts of the visual apparatus and in the central nervous system. Crozier (3, 4) has recently proposed a theory of visual threshold based upon neural units and their fluctuating variation in potential excitability. Night blindness due to vitamin A deficiency, according to Crozier, represents incipient neural injury in the form of a reduced capacity for excitation.

In the present study, children who had no apparent impairment of health were examined. Two socio-economic levels were represented. As part of an attempt to answer the question, what constitutes an elevated threshold, the socio-economic groups are compared with respect to adaptation, diets, and body measurements in the present report. The adaptation performance of the more favorably situated group is also described in detail to provide a reference relative to which unusual values for an individual within the age range of this study can be identified, if test conditions are the same.

Materials and Method

The Sample. The individuals examined were children attending school regularly and taking part also in extra-curricular activities. As judged by these functional criteria, the sample represented a group who had no apparent impairment of health. No gross opacities or abnormalities interfering with the transmission of light to the retina were reported in the medical examinations by the physician. Refractive anomalies were not measured and have not been corrected for the purpose of the dark adaptation test.

Children of families at a relatively high-income level were examined at a private high school in a semi-suburban locality adjacent to New York City. Children of families at a much lower income level were examined at a public high school on the lower East Side of Manhattan, New York. At both schools the children examined were those willing to participate in the study. In the high-income group, the children were with few exceptions of Jewish parents, born in the United States. In the low-income group most of the children were of Jewish parentage; about 17 per cent were from Italian families. In the majority of cases in the low-income group one or both parents were foreign-born.

Apparatus, Procedure of the Adaptation Test, and Other Observations. One adaptometer constructed according to the specifications of Hecht and Shlaer (11), and purchased in the commercial market[2] was used for all tests described in this report except those of seventy-two cases examined with a different one. The calibrations of the Corning 511 violet filters, the glass wedges, and "neutral" filters were checked by the National Bureau of Standards. The Macbeth Illuminometer was used to calibrate the light source. The instrument was operated in a suitable dark room. The test conditions were those previously employed in the cooperative nutrition study (12). For ease of reference the more important points will be summarized here.

Dark adaptation was preceded by three minutes light adaptation in the brightness range, 12.024-12.052 log $\mu\mu l$ in the case of the instrument used regularly. The preadaptation brightness of the second adaptometer with which seventy-two cases were tested was 11.793 log units. The test

[2] The adaptometer is constructed by O. C. Rudolph, 55 Van Dam Street, New York, N. Y.

field occupied 3 degrees visual angle in diameter. Light adapting and test fields were viewed 7 degrees nasally, using the right eye. The test light was exposed in flashes whose duration was .2 second. A Corning 511 violet filter, which transmitted wave lengths below 460 millicrons, was used during threshold determinations. The brightness of the threshold was expressed in the logarithm of micromicrolamberts ($\mu\mu l$). The dark adaptation period was 30-40 minutes, during which threshold determinations were made at intervals of 2-4 minutes. The method of determining the threshold has been fully described elsewhere (12). The measurements were made by laboratory technicians each of whom had previously examined about 200 subjects.

Preceding the dark adaptation test each subject had a physical examination including observations on the condition of the eyes. The lids, conjunctivae, and pupils were examined for evidence of obvious infection. Movement was tested. The Snellen test of visual acuity was made routinely.

Diet histories were obtained by interview. The kind and amount of foods and mixed dishes eaten in a two-day period immediately preceding the day of the interview were recorded.[8]

Anthropometric measurements were taken either on the day of the dark adaptation test or within a short interval.

Statistical Procedure. Threshold measurements of children in each income group were described by the statistical measures commonly employed to examine and summarize other psycho-physi-

[8] The commercial name or the brand or type of each food was obtained whenever possible together with a description of the manner in which the food was prepared. The child was questioned with regard to the composition of any mixed dishes reported, such as soup, stew, salads, and sandwiches and concerning the use of sugar, cream, butter, gravy, etc., with any of the foods or mixed dishes eaten. Quantity eaten was estimated relative to standard measure; cup, glass (large or small), teaspoon, tablespoon, sauce dish, which were available for display, or by reference to artificial casts of standard servings of frequently used mixed dishes. The enumeration included items eaten between meals and vitamin and mineral concentrates. Habits with respect to the frequency of use of protective foods, such as milk, eggs, fruits, and vegetables, were recorded. The child was questioned regarding types of activity, and their duration during the forty-eight hour period covered by the diet history. Over 500 recipes for mixed dishes frequently served were collected in the field and in the schools concerned to check upon the composition of mixed dishes reported by children. The approximate size of servings of various foods and mixed dishes used in the school lunches was also determined.

ological observations. At a given minute in the dark the set of threshold values obtained for all of the individuals concerned formed a frequency distribution characterized by clustering at a central value and dispersion in opposite directions.

With regard to early and late adaptation the frequency distributions of threshold at single minutes were found to be fairly symmetrical and to resemble the normal type. The ogives of threshold distributions before 5 minutes and after 9 minutes were found to be sufficiently rectified by a probability grid to justify the use of the mean and standard deviation to describe such distributions.

In the neighborhood of 5-9 minutes of adaptation, the frequency distributions of threshold were less symmetrical. In this period a strong skewed effect was evident and percentiles (the 90th, 75th, 50th, 25th, 10th) as well as the mean and standard deviation, have been relied upon to indicate levels of threshold above which were found the percentage of cases stipulated.

Subjects concerned in the present report were classified according to certain factors which were found to cause significant variation in threshold level. Thus, a preliminary analysis of results in 267 cases available early in the study showed that when the entire course of adaptation was to be considered, the subjects must be grouped according to income level, brightness of preadaptation, and the different technicians making the tests. If only the threshold later than 20 minutes were considered groupings were needed according to income and technician. At that time preadaptation differences were no longer significant (12).

Effects upon the mean or variance of threshold after 20 minutes, which might be due to a number of other factors, were also evaluated in the preliminary analysis of the results for 267 cases. Classifications for age, sex, acuity as measured by the Snellen test, pigmentation of the iris, hour of the test, time of color change from purple, violet, or blue to gray or white and phase of the menstrual cycle gave no evidence in a covariance analysis of differences in mean adjusted threshold after 20 minutes which could not be accounted for by chance.[4]

Adaptation at Different Income Levels

The mean threshold for children in the low-income group tended to be higher throughout adaptation than the mean for the high-income group. The difference was greater after 20 minutes of adaptation than at earlier times. Merging or crossing of the mean threshold levels were relatively infrequent and occurred before 20 minutes when adaptation was rapid and observational errors tend to be greater (12). Some uncertainty in the comparison resulted also from the small number of children involved and the fact that not every child could be examined at each minute. If these limitations are borne in mind, the mean performance of the two groups would appear to differ significantly before 20 minutes and in a manner consistent with the larger differences after 20 minutes.

Mean threshold intensity during adaptation for children in the high and low-income groups is shown in Table 1 and the corresponding Figure 1 in which threshold intensity (log $\mu\mu l$) is plotted against dark time.[5] All cases included in Table 1 were examined by one technician. The sixty-four cases of the high-income group were preadapted to 1,060, those of the low-income group to 1,080 millilamberts, a difference which would not account for the progressive differences in mean threshold level shown in Figure 1.

Larger subsamples of children at the two income levels indicated that the mean adaptation of the low-income group was not only slower but also more variable at corresponding dark times. The larger subsamples of children were obtained for the two income groups by combining 175 cases following 1,060 millilamberts pre-

[4] In testing the null hypothesis regarding sample means or variances the "F" distribution (27) has been used. In some instances Student's "t" was employed to test significance of mean difference (5). For either criterion, p.$\leq$ .01 was taken as the level of statistical significance.

[5] The time (minutes) elapsed after light adaptation and during dark adaptation.

Time in the Dark	Threshold[1]					
	High-Income Group—64 Cases			Low-Income Group—98 Cases		
	Observations	Mean	Standard Error	Observations	Mean	Standard Error
(Minutes)	(Number)	(Log $\mu\mu l$)	(Log $\mu\mu l$)	(Number)	(Log $\mu\mu l$)	(Log $\mu\mu l$)
0.5	63	6.372	±.014	98	6.460	±.014
1.5	1	6.059	—	—	—	—
2.5	57	5.844	±.021	81	5.887	±.016
3.5	5	5.784	±.065	17	5.900	±.048
4.5	31	5.576	±.021	16	5.596	±.036
5.5	32	5.416	±.037	78	5.521	±.020
6.5	21	5.283	±.028	7	5.375	±.202
7.5	28	4.990	±.093	42	5.158	±.076
8.5	13	4.547	±.182	41	4.475	±.077
10.0	38	4.051	±.030	21	4.202	±.054
11.0	17	3.905	±.098	41	4.046	±.063
12.0	8	3.952	±.217	31	3.847	±.040
13.0	33	3.626	±.035	15	3.718	±.057
14.0	19	3.436	±.041	31	3.656	±.044
15.0	13	3.375	±.112	45	3.474	±.038
16.0	28	3.278	±.039	15	3.408	±.035
17.0	24	3.176	±.030	29	3.326	±.035
18.0	5	2.954	±.105	34	3.245	±.034
19.0	25	3.065	±.054	25	3.125	±.049
20.0	27	2.960	±.034	28	3.118	±.039
21.0	11	2.866	±.064	22	3.111	±.036
22.0	23	2.799	±.056	39	3.019	±.028
23.0	26	2.706	±.036	20	2.871	±.046
24.0	15	2.712	±.065	35	2.978	±.032
25.0	15	2.640	±.052	34	2.859	±.024
26.0	28	2.569	±.037	15	2.891	±.066
27.0	19	2.560	±.031	35	2.810	±.034
28.0	15	2.512	±.044	31	2.803	±.033
29.0	24	2.455	±.020	24	2.797	±.034
30.0	21	2.478	±.114	35	2.700	±.039
31.0	14	2.450	±.097	33	2.726	±.034
32.0	25	2.414	±.030	20	2.726	±.054
33.0	20	2.430	±.035	21	2.652	±.050
34.0	19	2.440	±.037	39	2.655	±.037
35.0	18	2.387	±.016	26	2.655	±.043

[1] The observations were grouped in one minute intervals centered on the half minute before 9 minutes of adaptation and on the whole minute after 9.5 minutes, a procedure which followed the observed clustering of the data.

Table 1. Mean threshold and standard error, according to time in the dark, for children in the high and low-income groups who were preadapted to 1,060 millilamberts and 1,080 millilamberts respectively with one adaptometer by a single technician.

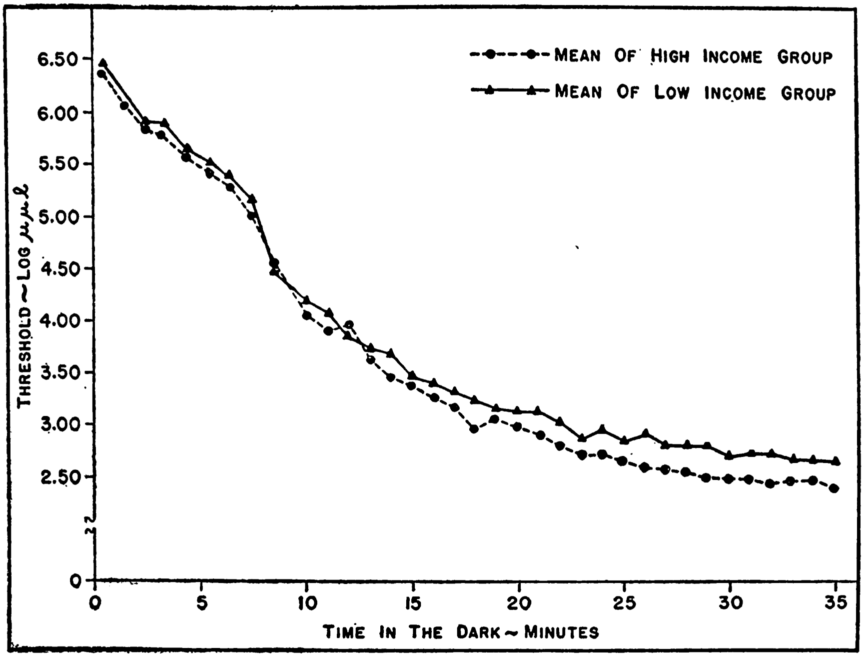

Fig. 1. Mean threshold during dark adaptation for children in the high-income group and in the low-income group, following 3 minutes preadaptation to 1,060 and 1,080 millilamberts, respectively.

adaptation tested by four technicians in the high-income group and by combining in the low-income group 240 cases tested by one of the same technicians and preadapted in the brightness range 1,117-1,127 millilamberts.

The greater number of technicians testing in the high-income group would tend to augment rather than decrease the variability of results in that group. The maximum difference in preadaptation (67 millilamberts) between the income groups, as represented in these subsamples, was insufficient to cause significant differences in mean threshold level or in variability after 20 minutes adaptation. Therefore, the comparison between income groups with respect to variability in adaptation performance has been made for thresholds after 20 minutes adaptation.

In Figure 2 the dispersion of threshold values after 20 minutes is illustrated for the two income groups by means of selected per-

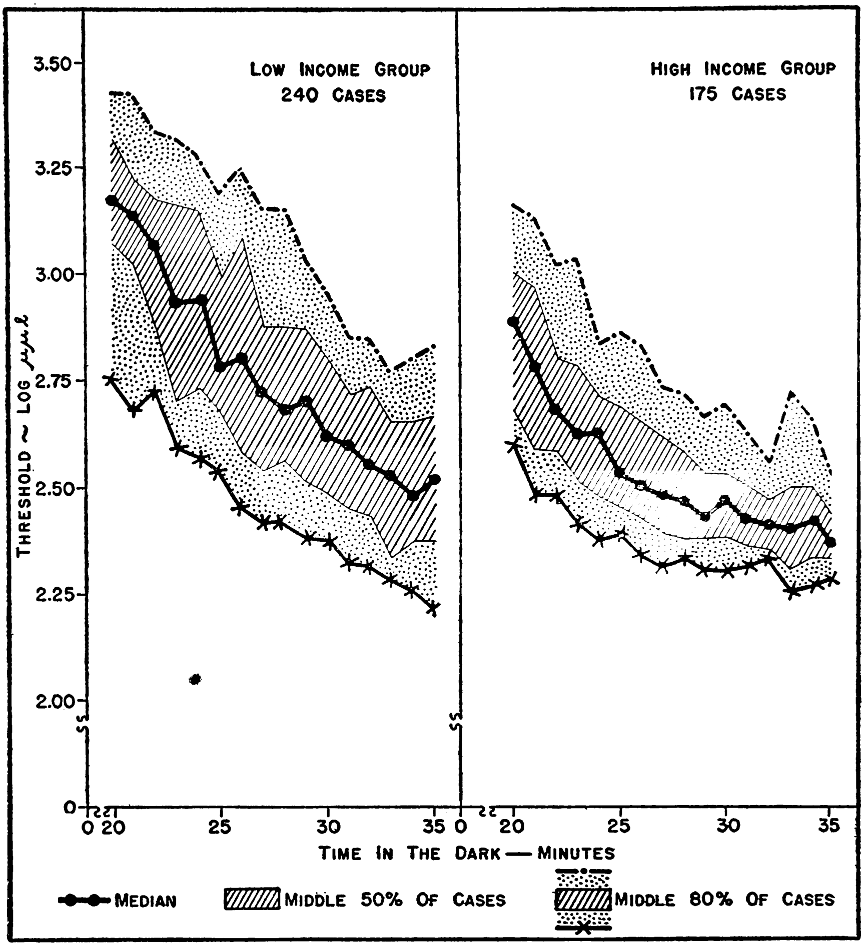

Fig. 2. Adaptation contours after 20 minutes in the dark for children in the high-income and in the low-income group following 3 minutes preadaptation to 1,060 and 1,080 millilamberts, respectively.

centiles of the frequency distributions of threshold at successive minutes. The adaptation contours so described showed quite different dispersions. At corresponding times the variability of the low-income group was greater throughout the interval, 20-35 minutes, and distributed about a higher median threshold level. In the high-income group the variability declined during 20-35 minutes more rapidly than in the low-income group. The relatively reduced variability expected toward the end of adaptation was found in the

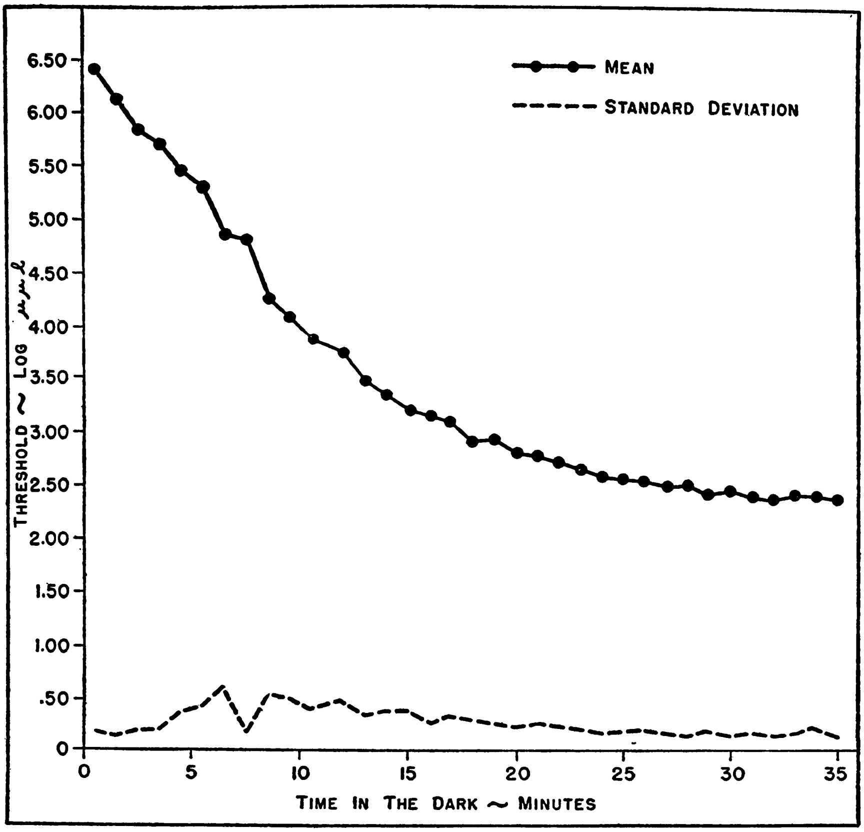

Fig. 3. Mean and variability of threshold during dark adaptation for 175 children of the high-income group examined by four technicians following 3 minutes pre-adaptation to 1,060 millilamberts.

high-income group by 35 minutes. At 30 minutes and later in the low-income group the variability was as great as that of the high-income group at 20 minutes.

The evidence of higher mean threshold and greater variability of the low-income group, shown in Figures 1 and 2, was supported by the results of the preliminary analysis for 267 cases referred to under statistical procedures. The preliminary analysis included the work of one technician at the public and private schools, which had been completed during one school year when the analysis was begun. The data covered sixty-four children of the 175 high-income cases whose results are shown in Figure 3 and seventy-two other high-income cases examined on the second adaptometer and not included in Figure 3 because their preadaptation was 11.793 log units as compared with 12.024 for the cases of Figure 3. The seventy-two cases could be included in the preliminary analysis in which preadaptation differences were controlled statistically. The low-income cases of the preliminary analysis were the ninety-eight children whose test results appear in Table 1 and thirty-three additional cases not included in Table 1 because of a preadaptation difference. In this analysis there were five or six threshold determinations for each subject after 20 minutes adaptation making a total of 1,579 observations for the 267 subjects.

The mean threshold level for the entire set of 1,579 observations after 20 minutes was 2.653 log units. The variability between cases measured by errors of estimate after linear regression was ± .421 log units. This figure represents the variability between mean thresholds of individual children after 20 minutes, independent of any small differences in mean observation time, and which were alike with respect to income, preadaptation, and technician.[6] Threshold values for the high and low-income groups differed significantly. The mean threshold levels after 20 minutes, adjusted to average observation time were 2.540 log units and 2.765 log units for the high and low-income groups respectively. The variability between cases (errors of estimate) for the high-income group was ± .330 log units and considerably greater for the low-income groups, ± .516 log units.

Threshold Characteristics of the High-Income Group. The test results throughout adaptation for the 175 cases of the high-income group are of interest as an indication of expected performance of an urban population of mixed bio-ethnic origin, not handicapped by unfavorable socio-economic circumstances. The tests were made by several experienced technicians and should therefore provide a

[6] The corresponding variance was .177 log units^2 associated with 245 degrees of freedom. This variance was used as "error" in the preliminary analysis.

more general description of adaptation results than can be obtained on the basis of a single technician. Inasmuch as adaptation measurements in different studies must usually be made by different tech-

Table 2. Mean, standard deviation, and standard error of threshold for 175 children of the high-income group after preadaptation for 3 minutes to 1,060 millilamberts, according to time in the dark.

Time in the Dark (Minutes)	Observations (Number)	Threshold: Mean (Log $\mu\mu l$)	Threshold: Standard Deviation (Log $\mu\mu l$)	Threshold: Standard Error (Log $\mu\mu l$)
0.5	172	6.436	±.187	±.014
1.5	3	6.145	±.149	±.086
2.5	157	5.847	±.198	±.016
3.5	15	5.722	±.219	±.056
4.5	105	5.473	±.360	±.035
5.5	59	5.323	±.445	±.058
6.5	79	4.851	±.614	±.069
7.5	66	4.828	±.176	±.022
8.5	66	4.259	±.554	±.068
9.5	55	4.088	±.496	±.067
10.5	76	3.879	±.397	±.046
12.0	53	3.748	±.479	±.066
13.0	85	3.479	±.345	±.012
14.0	63	3.352	±.384	±.048
15.0	46	3.218	±.381	±.056
16.0	78	3.181	±.282	±.032
17.0	56	3.100	±.342	±.046
18.0	49	2.902	±.313	±.045
19.0	61	2.936	±.284	±.036
20.0	54	2.831	±.242	±.033
21.0	48	2.779	±.250	±.036
22.0	51	2.714	±.241	±.034
23.0	56	2.656	±.219	±.029
24.0	56	2.607	±.194	±.026
25.0	51	2.597	±.184	±.026
26.0	58	2.552	±.193	±.025
27.0	55	2.508	±.169	±.023
28.0	50	2.511	±.159	±.023
29.0	59	2.457	±.180	±.023
30.0	56	2.463	±.154	±.021
31.0	48	2.436	±.160	±.023
32.0	51	2.409	±.151	±.021
33.0	50	2.445	±.172	±.024
34.0	58	2.423	±.220	±.029
35.0	50	2.398	±.127	±.018

nicians a general description which includes technician peculiarities is a safer reference in comparisons than one which is limited to a single observer, provided that the several technicians are competent.

No definite specifications can be given with regard to the vitamin A nutrition of the high-income group. No doubt numerous individuals were included whose vitamin A nutrition was not optimal. Identification of such cases can be made only by subsequent and suitable experiment. The sample was not, therefore, representative of a well-nourished population in a strict sense.

Threshold Distributions During Adaptation. Mean threshold, standard deviation, and standard error are given for the 175 cases of the high-income groups in Table 2 for each minute up to 36 minutes dark time. The mean threshold at 30 minutes was 2.463 log units and the standard deviation, .154 log units. In the neighborhood of 30 minutes dark time the entire range of thresholds observed was approximately 1.0 log unit. The variability of threshold increased rapidly during the first 7 minutes of the test, at which time it apparently reached a maximum and then declined, reaching at 25 minutes values comparable to those obtained immediately after preadaptation. The fluctuation of the standard deviation is closely correlated with observational error, which in turn is associated with rate of adaptation. The larger standard deviations in the interval, 5-10 minutes, also reflected differences among the 175 cases with respect to onset of secondary or "rod" adaptation. Figure 3 illustrates the regression of mean threshold and the variability.

The frequency percentage distributions of threshold at 0.5, 4.5, 8.5, 13.0, 17.0, 21.0, 25.0, 29.0, and 33.0 minutes are shown in Figure 4. Greater concentration of values was evident early and late in adaptation and marked skewed effects in the same direction were obtained at 8.5 minutes and at 25, 29, and 33 minutes.

Several percentiles were used to illustrate more clearly the change in form of the successive distributions. The threshold values corres-

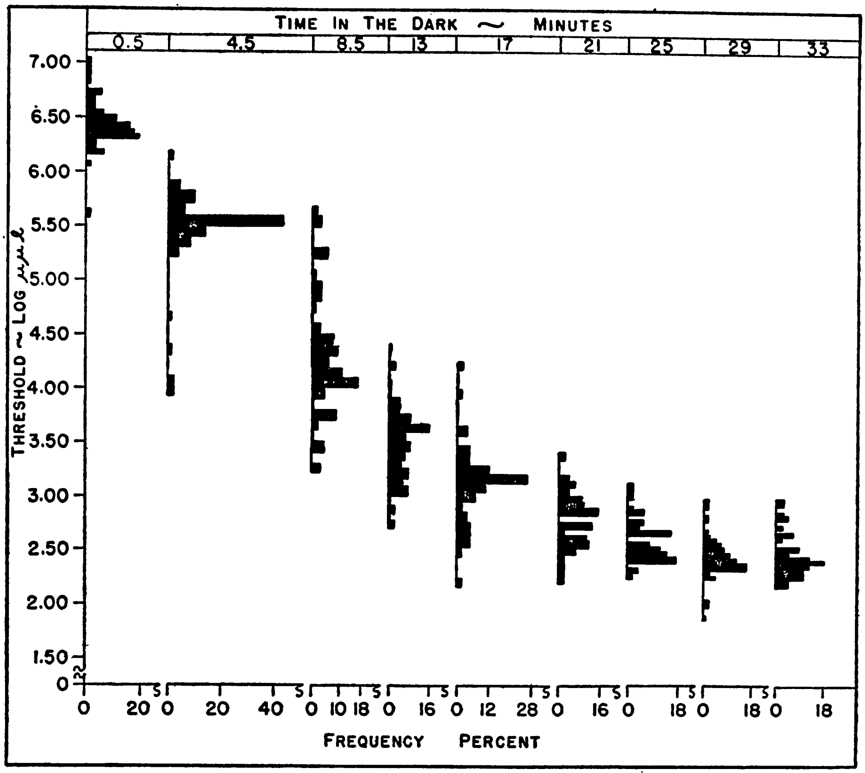

Fig. 4. Frequency percentage distributions of threshold at specified times during dark adaptation for 175 children of the high-income group examined by four technicians, following 3 minutes preadaptation to 1,060 millilamberts.

ponding to the several percentiles were interpolated from the distribution at each minute, except at 1.5 minutes and between 11-11.5 minutes when only a few cases were observed. The percentile values are given in Table 3. Figure 5 shows the adaptation contour for the middle 80 per cent and middle 50 per cent of cases up to 36 minutes.

The adaptation of the middle 50 per cent appeared to be complete at about 30 minutes. Before 6 minutes and after 10 minutes the middle 50 per cent of cases were distributed symmetrically about the median. Owing to differences among individuals with respect to time of maximum rate of adaptation skewed effects in opposite directions occurred immediately preceding and following the 7.5 minute point. Judged by the median the maximum rate of adapta-

Time in the Dark (Minutes)	Observations (Number)	Threshold at Specified Percentiles				
		90th (Log $\mu\mu l$)	75th (Log $\mu\mu l$)	50th (Log $\mu\mu l$)	25th (Log $\mu\mu l$)	10th (Log $\mu\mu l$)
0.5	172	6.68	6.50	6.40	6.33	6.23
2.5	157	6.08	5.98	5.87	5.73	5.55
4.5	105	5.77	5.60	5.54	5.45	5.30
5.5	59	5.75	5.58	5.39	5.24	4.69
6.5	79	5.54	5.30	5.20	4.32	4.06
7.5	66	5.38	5.27	5.18	4.28	3.95
8.5	66	5.21	4.47	4.15	3.96	3.65
9.5	55	4.78	4.34	4.11	3.78	3.38
10.5	76	4.30	4.17	3.90	3.67	3.31
12.0	53	4.28	3.99	3.64	3.46	3.26
13.0	85	3.86	3.69	3.51	3.21	3.05
14.0	63	3.68	3.50	3.35	3.13	2.91
15.0	46	3.63	3.46	3.20	2.99	2.70
16.0	78	3.50	3.36	3.19	2.95	2.83
17.0	56	3.43	3.26	3.14	2.91	2.62
18.0	49	3.33	3.09	2.90	2.68	2.51
19.0	61	3.23	3.11	2.93	2.72	2.56
20.0	54	3.16	3.00	2.89	2.68	2.60
21.0	48	3.14	2.97	2.78	2.59	2.48
22.0	51	3.02	2.80	2.69	2.58	2.48
23.0	56	3.03	2.79	2.63	2.51	2.41
24.0	56	2.83	2.71	2.62	2.47	2.37
25.0	57	2.86	2.69	2.53	2.45	2.39
26.0	58	2.83	2.65	2.50	2.42	2.33
27.0	55	2.73	2.61	2.48	2.39	2.31
28.0	50	2.71	2.58	2.47	2.38	2.33
29.0	59	2.66	2.53	2.43	2.37	2.30
30.0	56	2.69	2.53	2.47	2.38	2.30
31.0	48	2.60	2.50	2.42	2.36	2.31
32.0	51	2.55	2.47	2.41	2.35	2.33
33 0	50	2.72	2.50	2.40	2.30	2.25
34.0	58	2.66	2.50	2.42	2.33	2.26
35.0	50	2.53	2.43	2.37	2.33	2.28

Table 3. Threshold, at specified percentiles of the frequency distributions for the 175 cases of the high-income group who were preadapted for 3 minutes to 1,060 millilamberts, according to dark time.

tion occurred just about 7.5 minutes. After 20 minutes the percentiles above the 75th departed progressively toward higher threshold values.

Correlation between Threshold Early and Late in Adaptation.

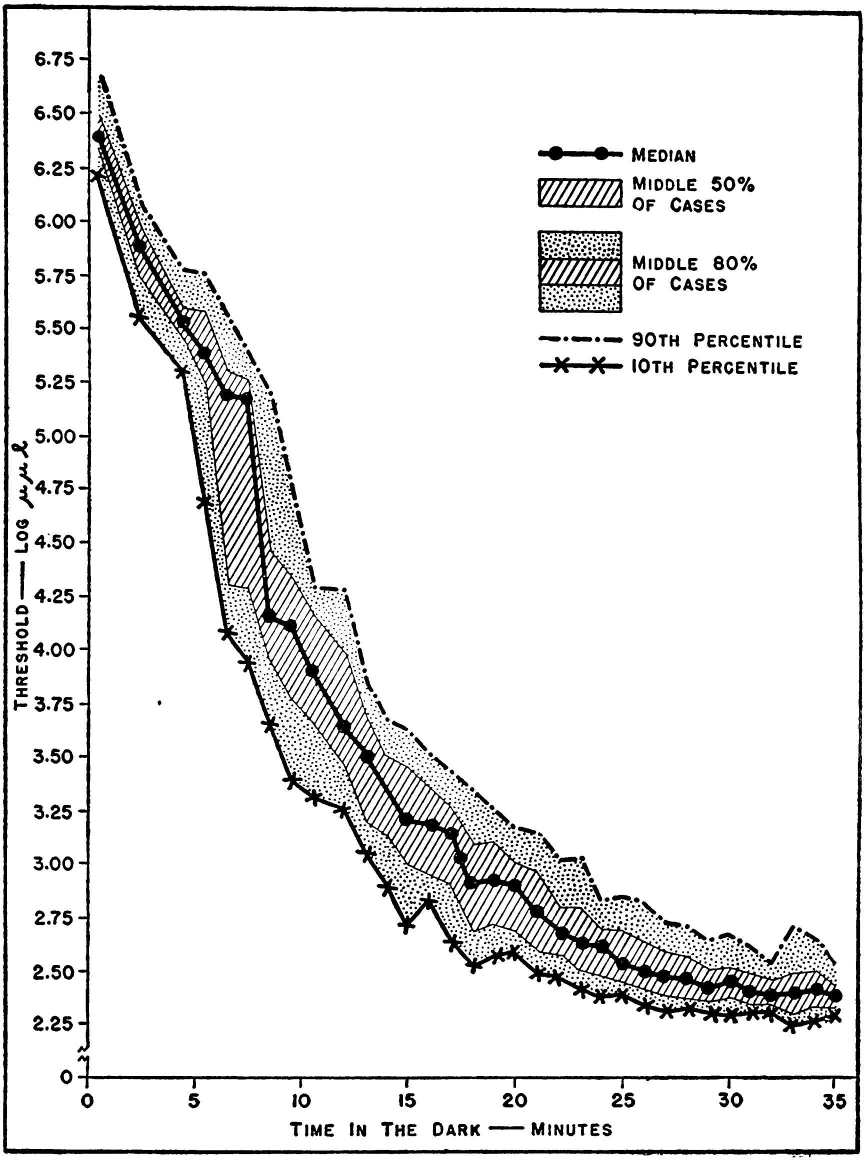

Fig. 5. Dark adaptation contour for 175 children of the high-income group who were examined by four technicians and preadapted for 3 minutes to 1,060 millilamberts.

The correlation between mean threshold at 30-35 minutes and thresholds obtained earlier in adaptation indicated that the rank order of a child early in the test was not a dependable indication of

Time in the Dark (Minutes)	Observations (Number)	Coefficient of Correlation (r) (Number)	Standard Error of Estimate (s y.x.) (Log $\mu\mu l$)	Regression Coefficient (b) (Number)	Variation in Threshold Accounted for by Regression (r^2 x 100) (Per Cent)
2.5	155	+.0924	±.194	+ .127	0.8
4.5	104	−.0192	±.360	− .048	0.0
10.0	82	−.0203	±.398	− .057	0.0
13.0	85	+.1058	±.344	+ .262	1.1
16.0	78	+.3587	±.284	+ .952	12.9
18.0	47	+.4127	±.295	+ .912	17.0
24.0	54	+.4949	±.172	+ .703	24.5
26.0	58	+.8593	±.099	+1.057	73.8
29.0	58	+.9314	±.067	+ .825	86.8

Table 4. Correlation statistics for mean threshold after 30-35 minutes dark adaptation and threshold after specified shorter periods of adaptation, following 3 minutes preadaptation to 1,060 millilamberts.

his rank for mean threshold at 30-35 minutes. Summarized in Table 4 are coefficients of correlation and related statistics for mean threshold at 30-35 minutes and threshold determined at each of nine other dark times. The coefficient of correlation was not significant until 16 minutes when the value was + .35. Not until 26 minutes was the relationship to the mean threshold at 30-35 minutes sufficiently close to be of practical importance. The change from fairly close relationship at 26 and 29 minutes to independence before 16 minutes is shown in Figure 6.

Diets and Body Measurements of Children in the High and Low-Income Groups

The diets and body measurements of the high and low-income groups are of interest in view of the known association of threshold elevation with nutrition and the relation of the latter to growth of the body. At this time diet descriptions can be given for the 267 children of the high and low-income groups shown by the preliminary analysis to differ significantly with respect to adjusted mean threshold level after 20 minutes adaptation and with respect to variability of adaptation as well. There were in this subsample

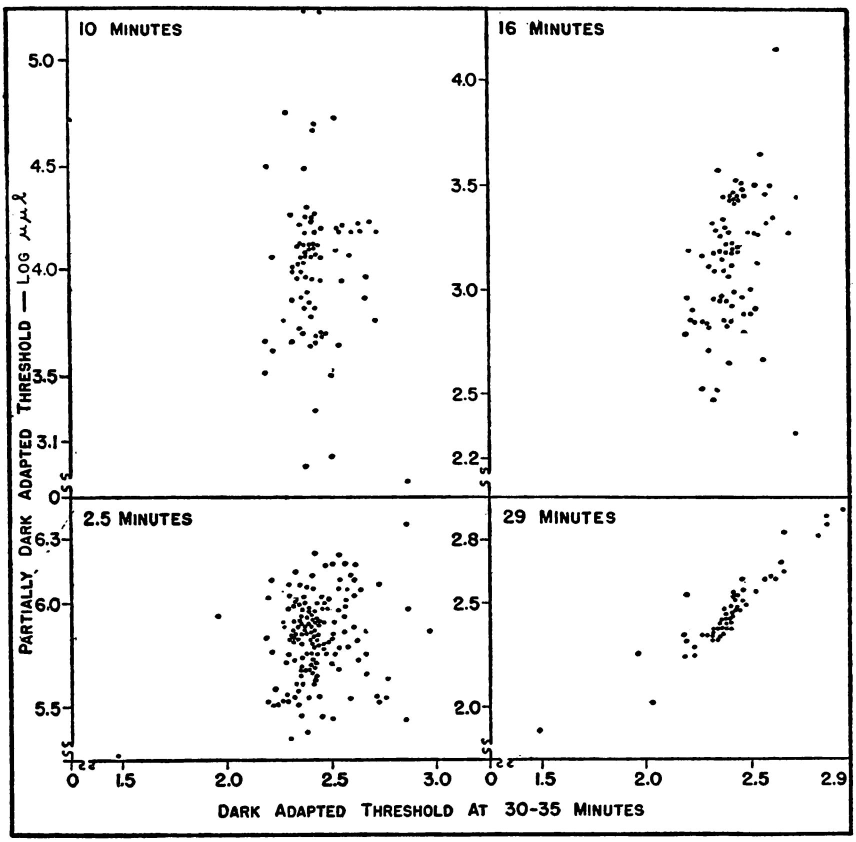

Fig. 6. Correlation of the mean threshold after 30-35 minutes in the dark and partially dark adapted thresholds following preadaptation for 3 minutes to 1,060 millilamberts.

136 children of the high-income group and 131 children of the low-income group. It is believed that the present diet descriptions although limited to 267 children are representative of the dietaries characteristic of persons in the two income groups whose adaptation is described. A full analysis and discussion of the diets will be given in other reports. Comparison of body development of the children in the two income groups was made on the basis of the full sample of children examined at each income level in the nutrition study. It was found that the stature, weight, and age distributions of the cases whose adaptation and diets are described did not differ significantly from those of the respective samples.

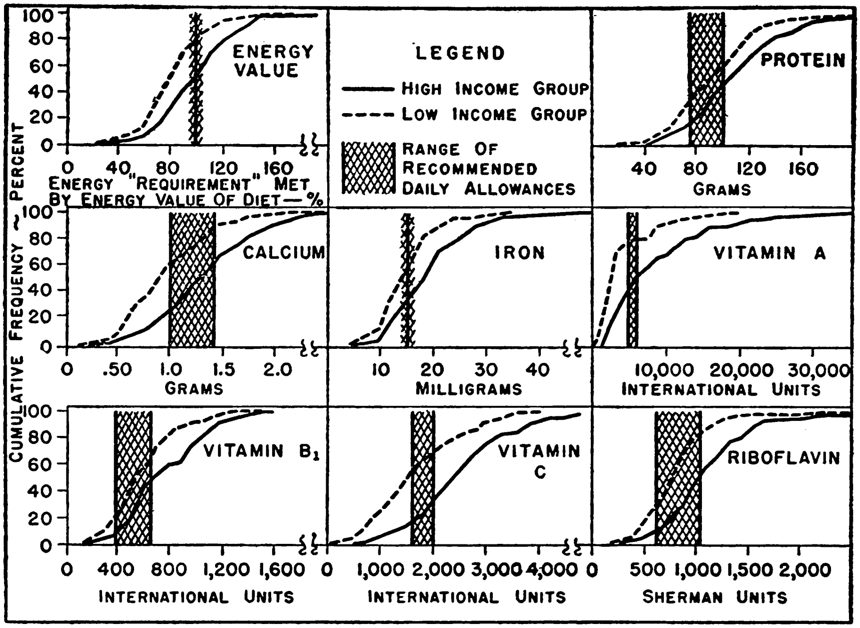

Fig. 7. Cumulative frequency percentage distributions for per cent of daily energy allowance met by the diet and for quantities per day of specified nutrients of the diets of 136 children of the high-income group and 131 children of the low-income group.

Nutritive Content of the Diets. The estimates of nutritive content are subject to the uncertainties inherent in the interview method and in the application in particular cases of average values for food composition. The procedure of interview was uniform in the two income groups and it is likely that the relative position of the groups is reflected approximately although the estimates of nutritive content may not correspond exactly with those which would be obtained by another method.

Recommended daily allowances of different nutrients serve as a rough yardstick to indicate dietary "adequacy" from the point of view of practice tentatively regarded as desirable. In Figure 7, a recommended range or level of daily allowance is shown for protein; calcium; iron; and vitamins A, B, C; and riboflavin.[7] The

[7] The daily allowances indicated graphically are based upon quantities of the specified nutrients which were recommended for boys in the age groups, 13-15 years and 16-20 years, and for girls in the same age groupings (23). With the exception of four 12-year-old

(Continued on page 271)

quantities of the several nutrients provided by the respective diets of the two income groups are compared with the recommended allowances by means of cumulative frequency distributions for each nutrient. In this general comparison sex and age groups have been combined.

In the case of energy value, individual "requirements" per twenty-four hours were computed according to basal caloric "requirements" for age, sex, surface area, and estimates of need for growth and type of activity reported on the child's diet history. The energy value provided by the child's diet as described was then expressed in per cent of the child's "requirement."

Thus in Figure 7, the panel for energy value shows the percentage of children having diets which provide varying proportions (in per cent) of the individual energy "requirement." Regardless of the basis of estimating individual energy requirements Figure 7 indicates that the percentage of diets meeting energy "requirement" in the low-income group was considerably smaller than corresponding percentages of the high-income group.

Large differences occurred with respect to daily vitamin A intake. Approximately 78 per cent of the diets of the children in the low-income group and 44 per cent of the diets in the high-income group were providing less than 5,000 I.U. per day.

With respect to daily intake of protein, vitamins B_1 and riboflavin the diets of the majority of children in both income groups appeared to be satisfactory relative to the tentative and approximate allowances. However, for each of these nutrients the diets of larger percentages of children of the low-income group than the high-income group fell short of recommended daily allowances.

Fifty-two per cent of the children of the low-income group and

boys and six 12-year-old girls, the ages of all children whose diets are discussed in this report were in the age range 13-19 years. In Figure 7 the least quantity recommended in the age groupings, 12-15 years, 16-20 years, for either sex was used as the lower limit of the indicated range of daily allowance. The upper limit corresponds to the largest quantity recommended among the four age-sex groups.

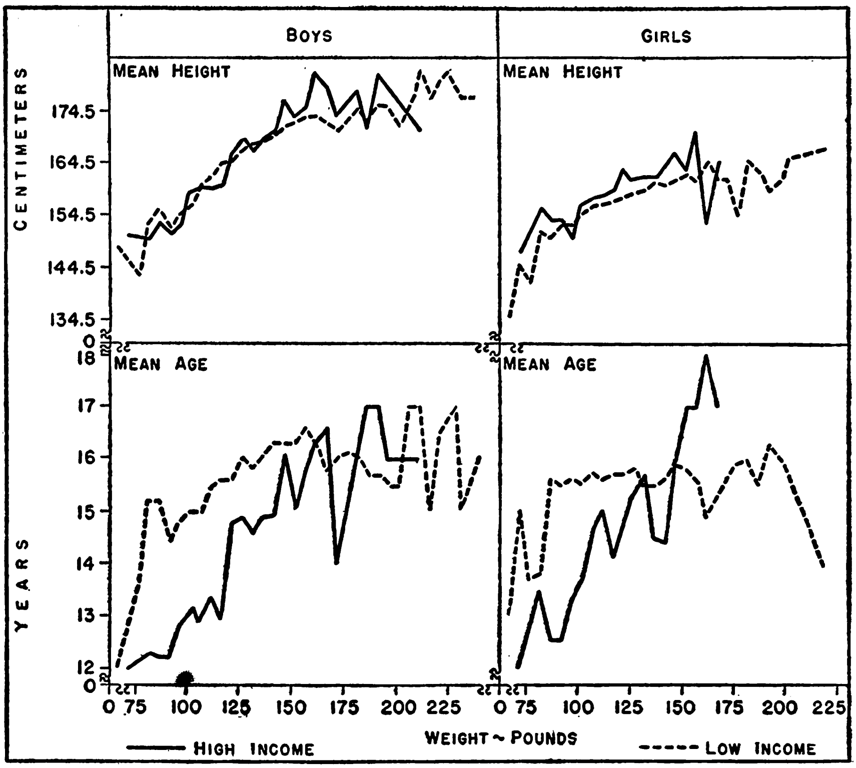

Fig. 8. Mean height and mean age according to weight, for 183 boys and 171 girls of the high-income group and for 1,169 boys and 1,020 girls of the low-income group.

18 per cent of the high-income cases were receiving less than the recommended allowance of vitamin C. Similar percentages of the diets fell below a daily allowance of 1.0 gram of calcium.

Stature, Weight, and Age. Full consideration of differences in body measurements cannot be given here but differences were outlined according to the relationship between stature, weight, and age. For equal weight the children of the low-income group tended to be shorter and older. Mean stature and mean age according to weight are shown in Figure 8. It was found that boys with body weight of less than 162 pounds (86 per cent of low-income classes, 90 per cent of high-income cases) attained equal weight in a shorter mean growth period in the high-income group. Similarly, for girls with body weight less than 147 pounds (89 per cent of low-income cases, 92 per cent of high-income cases) the mean growth period to reach equal weight was shorter for the high-income group. Mean stature for equal weight and younger age was greater in the high-income group, quite consistently for girls and frequently in the case of boys.

Discussion

In this survey visual sensitivity was found to be correlated with income level. The relationship has been reported also in other studies of apparently well persons. (14, 22, 20, 24, 17.) The difference found here between income groups in mean threshold after 20 minutes was small (.225 log units after 20 minutes), but it tended to increase with dark time. The pattern of difference shown in Figure 2 resembles threshold changes reported as associated with vitamin A deficiency (2, 31, 9), and with reduced oxidation in hypoglycemia (19). The diet descriptions of the respective income groups indicated that the vitamin A intake and energy value of the diets of the low-income group were less satisfactory, relative to recommended daily allowances, than were those of the high-income group. Thus the dietary evidence supported an interpretation that the differences in visual sensitivity of the two groups might be a reflection of different levels of vitamin A intake and differences with respect to available glucose and its metabolism. However, the degree of the relationships between visual sensitivity, vitamin A intake, and glucose metabolism is highly uncertain. In several experiments, human subjects have failed to show threshold elevation when vitamin A was withheld from the diet (28, 13). In the present study, data bearing directly upon the question of differences in capacity to oxidize glucose were not available.

Since changes in visual sensitivity during adaptation following vitamin C therapy have also been reported (29) and the diets of the children of the two income groups concerned here differed almost as widely with respect to vitamin C as vitamin A, the additional question is raised whether this nutrient may not also have contributed to the different visual response of the two groups. Neither the latter possibility nor the relative roles of vitamin A and glucose metabolism in visual efficiency can be accurately evaluated on the basis of present knowledge.

The income groups showed differences which may be of nutritional origin not only in visual function but also in body development as indicated by stature, weight, and age. The differences in body development were too great to be explained entirely by body build. The fact that in the majority of cases children in the low-income group were shorter for equal weight might be attributed in part to relatively greater cross-sectional growth and skeletal differences. But the greater age for equal weight in addition to shorter stature suggested a retardation in growth.

Night blindness due to vitamin A deficiency is customarily interpreted according to the duplicity theory of vision (26) and the photochemical hypothesis (15, 8). These theories largely disregard the effects upon visual response of nerve, of the central parts of the visual apparatus, and of the central nervous system. The evidence of change in cerebrospinal fluid pressure preceding night blindness and the appearance of very early lesions of the optic tract and medulla in vitamin A deficiency cannot be brought within the framework of a photochemical explanation. Crozier's interpretation of dark adaptation is of interest because, among other reasons, it considers the co-functioning of receptor cells and of intermediary and central parts of the visual mechanism in relation to the central nervous system in general.

Crozier's theory assumes that visual response results from the stimulation by light of excitable neural units which momentarily fluctuate in intensity threshold at random. It is presumed also that during adaptation the neural units vary in capacity to produce nerve impulses when stimulated. In all available series of measurements

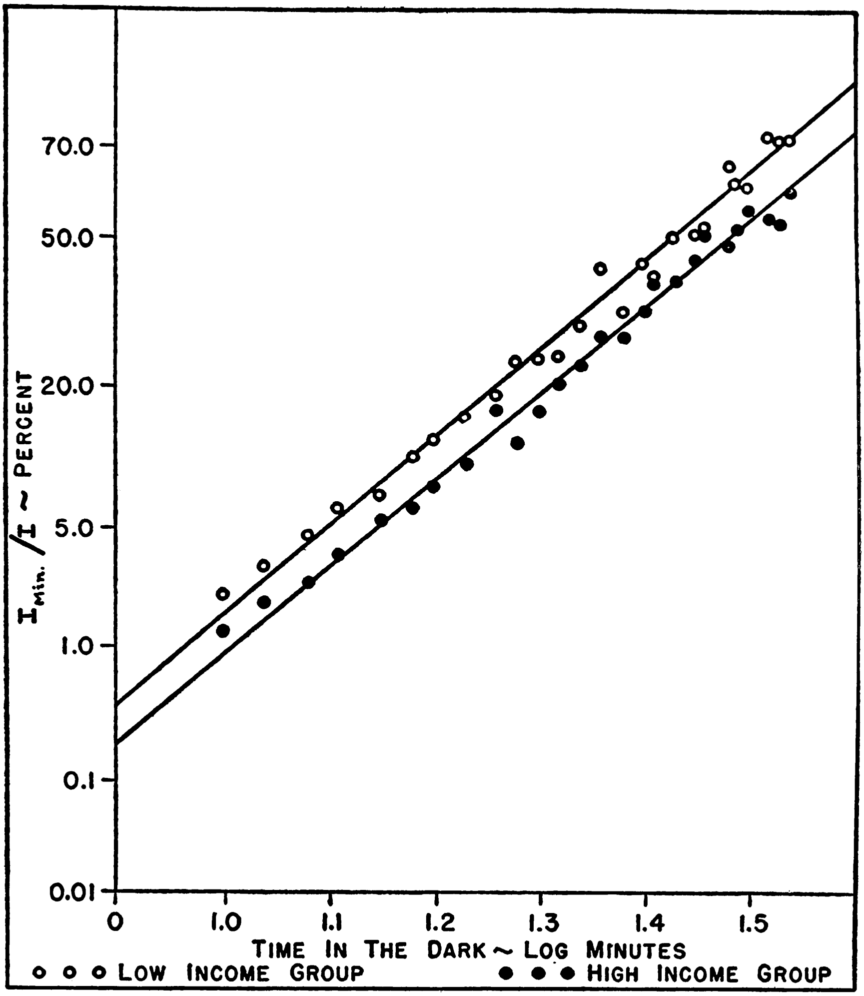

Fig. 9. Mean excitability at successive minutes after 9 minutes dark time, in per cent of maximum mean excitability for ninety-eight children of the low-income group preadapted for 3 minutes to 1,080 millilamberts and for sixty-four children of the high-income group who were preadapted for 3 minutes to 1,060 millilamberts.

of man and of all other animals that have been tested Crozier has shown that threshold during dark adaptation can be expressed by a probability integral as a function of log dark time (3, 4).

The dark adaptation response of the children in the different income groups, described in Table 1, is represented in Figure 9 on a probability grid. The ordinate is the ratio in per cent of the theoretical minimum threshold intensity (I_{min}) at the end of the adaptation and threshold intensity (I) at each observation time. This ratio ($\frac{I\ min}{I}$ x 100) is presumed to express excitability ($\frac{1}{I}$) during adaptation in relation to final or maximum excitability, which is the reciprocal of the minimum threshold intensity ($\frac{1}{I\ min}$).

Considerable scatter of the points is evident and might be expected in view of the fact that means based upon different subjects have been used and case composition fluctuated at successive minutes. The theoretical minimum threshold for the low-income groups was 2.506 log units. The corresponding value for the high-income groups was 2.156 log units. The lower minimum threshold of the high-income group signifies a greater capacity of neural units to produce nerve impulses or neural effects. In Figure 9 the equal slope of the lines may be taken to indicate that comparable groups of neural units are involved.

In school or community surveys of dark adaptation the majority of subjects can be tested only once and performance of the individual is judged according to the expected threshold of subjects who are apparently well and who have been tested under the same conditions. The dark adaptation results in Table 3 for the children of the high-income group indicate the range of threshold values to be expected of the middle 80 per cent of children who are apparently well and in the age range 12-19 years. The percentiles provide a method of describing conveniently the usual threshold values of this group. Despite case fluctuation at successive minutes, selected percentiles after 20 minutes may very well reflect to a considerable extent the threshold level of children who have relatively the highest, the lowest, and the middle threshold values. Usual performance, as shown by the middle 50 per cent of cases, was between 2.68 and 3.00 log units at 20 minutes and between 2.38 log units and 2.53 log units at 30 minutes. The skewness toward higher values of percentiles above the 75th after 20 minutes suggested that children so placed may be unable to complete the final phases of adaptation as successfully as the middle 50 per cent which was more symmetrically distributed. Judged according to the threshold distributions of this study, test results which fall consistently above 3.00 log units (75th percentile) after 20 minutes are unusually high and the subjects concerned are worthy of additional study.

Since the visual threshold as measured is a psychometric observation it was thought that the child's general aptitude in school might have some effect upon his test results. The upper and lower 25 per cent of the children ranked according to the adaptation test results, were compared with respect to school behavior, to obtain a preliminary indication of whether such a relationship might be involved. Satisfactory quantitative ratings for school behavior were not available and the opinion of teachers and supervisor was the basis of rating for adjustment in school. The comparison suggested that performance on the test may be related to success in academic work, social adjustments, and emotional stability. A relatively large number of children who were thought to be ill-adjusted in school ranked poorly on the test whereas only a few children so regarded by the school authorities were found among the 25 per cent of children whose adaptation reached the lowest threshold levels. On the basis of this limited comparison the correlation between school behavior and test performance can only be suggested in the form of a question.

Pathogenetic studies of threshold elevation due to vitamin A deficiency have shown in certain cases that thresholds late in adaptation respond to lack of vitamin A sooner and to a greater extent than earlier thresholds. (2, 31, 10). It would appear to be advisable, therefore, to give considerable weight to performance after 30-35 minutes if the object of the observations is an early reflection of avitaminosis A. The negligible correlations between threshold at 30-35 minutes and much earlier thresholds suggest that thresholds before 26 minutes do not give dependable information regarding those of the later stages of adaptation. If the information desired concerns the relative performance of the individual after 30 minutes adaptation, the threshold should be observed at that time. In serial studies of experimental night blindness and of individuals with cirrhosis of the liver (7) thresholds early and late in adaptation have been found to be more highly correlated than those described here. Subjects in such studies become experienced and the loss of correlation due to observational error is less than in the situation where the subjects are examined only once.

Summary

1. Visual threshold measurements, diets, and body measurements of high school children, 12-19 years of age, at different income levels are described. The threshold measurements were made with the Hecht adaptometer according to specified test conditions.

2. The mean threshold after 20 minutes, for 131 children of the low-income group was 2.765 log units with a variability (errors of estimate) of ± .516 log units. The corresponding values for 136 children in the high-income group were 2.540 log units ± .330 log units.

3. Seventy-eight per cent of the diets of the children in the low-income group and 44 per cent in the high-income group were providing less than 5,000 I.U. vitamin A daily. Larger percentages of the diets in the high-income group than in the low-income group were providing energy value; protein; calcium; vitamins B_1, C; and riboflavin in satisfactory quantities as judged by tentative and approximate allowances recently recommended.

4. The relationships between mean height and mean age with weight constant showed that the majority of children of the high-income group were taller and younger for equal weight than those of the low-income group.

5. Mean threshold level after 20 minutes was not affected in either income group by age, sex, acuity as measured by the Snellen test, pigmentation of the iris, hour of the test, time of color change from

purple, violet, or blue to gray or white, or phase of the menstrual cycle.

6. The mean threshold level at 30 minutes for 175 cases of the high-income group, examined by four technicians and preadapted to 1,060 millilamberts was 2.463 log units with a standard deviation of ± .154 log units. The range at 30 minutes was 1.0 log unit. Judged by the median the maximum rate of adaptation occurred just after 7.5 minutes dark time.

7. Mean threshold at 30-35 minutes was unrelated to threshold levels measured before 16 minutes dark time. Large observational errors early in adaptation would tend to obscure an actual correlation between late and early thresholds. Early thresholds are not a good index of results which would be obtained after 25 minutes dark time.

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