THE EFFECT OF VARIATIONS IN IRIS PIGMENTATION UPON VISUAL ADAPTATION

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By

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PREFACE

My aim in the preparation of this thesis has been to determine the effect of variations in iris pigmentation upon visual adaptation. I have endeavored to determine the effect of variations by selecting equal numbers of dark-eyed and light-eyed high school students and testing their comparative abilities as to the length of time it takes to perceive an opening in a Landot ring when passing from darkened to lighted conditions and visa-versa.

I am obligated to Dr. E. L. Stromberg for his many helpful suggestions, continued interest and cooperation in setting up the experiment and writing the thesis. I am also obligated to Dr. S. L. Reed and Dr. J. C. Muerman who have offered helpful criticisms, and to Virginia Harrison, librarian, all of the Oklahoma A. and M. College. I wish to express my appreciation to Dr. R. E. Leatherrock of Cushing, Oklahoma, for making the visual acuity tests of the subjects. Thanks for particular favors are due Jake Shellhammer, Thurston B. Swartz, R. Z. Simmons, Mrs. Edra Beall, my wife; and to the students for their kind cooperation and help.

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CHAPTER I

INTRODUCTION

The writer became interested in variations in visual adaptation in relation to iris pigmentation by observing the ability of his wife, who has brown eyes, to see more distinctly than he, who has blue eyes, when exposed to car headlights while driving at night; and her apparent ability to distinguish objects more quickly when passing from lighted conditions to darkened conditions. It was also observed that she has a smaller pupil diameter as well as higher sensitivity in lighted conditions. The diets for both have been practically the same for several years, the visual acuities are normal, and there is very little age difference. The writer became interested and curious to learn whether the variations in visual adaptations are due chiefly to diet, photochemical processes due to visual purple degeneration in lighted conditions and regeneration in darkened conditions, or due partly to iris pigmentation.

The importance of pigment cells have been stressed by Zikulenko and Adler[1] who testify that the rod and cone cells are not in themselves the fundamental light receiving unit. One of these rod or cone cells functioning in connection with a pigment cell forms the light receiving unit.

We are aware of the fact that dark objects absorb light better than light colored ones and if light, as in the case of eyes, does affect the pigment chemically, as pointed out by Wald,[2] it would surely have to be absorbed to be effective.

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1 F. H. Adler, "A Comparitive Study of the Role of Pigment in the Physiology of Vision." Arch. Ophth., LVII, 346-359, 1938.

2 G. Wald, "Carotenoids and the Visual Cycle." Journal of Gen. Physiol., XIX, 351-368, 1935.

Guilford[3] has observed the threshold of visual sensitivity for light eyes to be greater than for dark ones, thus it appears that dark eyes should be more sensitive to light.

At this point the distinction between visual sensitivity and visual acuity should be made clear. The visual sensitivity experiment as performed by Helson and Guilford takes as the threshold measurements the amount of light necessary to evoke sensation (light minimum) as against the ability to distinguish the object clearly (form vision) used by Hecht, Jeghers and others.

The relation of the retinal and choroidal pigment to iris color is almost one to one.[4] The pigment of the retina belongs to the stratum pigmenti or third layer, while the pigment epithelium of the iris belongs to the tunica iterna or fourth layer; the relation between the two is so close that a lightly colored iris will have a less pigmented fundas and visa-versa for the darkly colored iris.

From Cajal's[5] sketch it is shown that between the stratum of rod cells and cone cells and the choroid is a layer of pigmented cells, processes from which extend between and envelop the rods and cones.

Helson and Guilford[6] have shown that albinos and light eyed subjects short in retinal pigment are less sensitive to light than are dark eyed subjects. It has also been found that a diaphragm placed in front of the albino's eyes raises the threshold of visual sensitivity, whereas for normals, or darker eyes, no appreciable difference could be cited within certain limits.

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3 J. P. Guilford, "Fluctuations of Attention with Weak Visual Stimuli." American Journal of Psychol., XXXVIII, 434-454, 1927.

4 H. Helson and J. P. Guilford, "The Relation of Visual Sensitivity to the Amount of Retinal Pigmentation." Jour. of Gen. Psychol., IX, 58-76, 1933.

5 J. D. Lickley, The Nervous System, p. 92, fig. 82, Longmans Green and Co., New York, 1920.

6 H. Helson and J. P. Guilford, op. cit. above.

The darker the eye, the less transparent the iris. This leads one to believe that the iris pigment of albinos and other extremely light-eyed subjects is, to a certain degree, transparent. The variation in pupil diameters as shown by Reeves[7] is probably due to iris absorption, stratum pigmenti absorption and iris transparency.

Jeghers[8] has shown that vitamin A deficiency causes night-blindness but that is common to all subjects regardless of eye color. The question is; "In which type of subject, light or dark-eyed, will night-blindness and light-blindness be more prevalent?" In Jeghers' experiment iris pigmentation was not taken into account when improvements, due to Vitamin A therapy, were made. Another question one might ask is, "Which group of subjects would respond the better to vitamin A therapy?"

Helson and Guilford[9] have shown that the critical ratio or statistical reliability is 2.39 in favor of the dark-eyed whites as against the light-eyed whites, computed by the mean. This tells us that the chances are about 992 out of a 1000 that the true difference between the dark eyes and the light eyes is greater than zero. The critical ratio is 1.6 in favor of the dark-eyed whites as against the medium colored eyed whites. This tells us that the chances are about 945 out of a 1000 that the true difference in this comparison is greater than zero. The statistical reliability in the peripheral areas are of much less significance but the heavily pigmented eyes are favored, especially the negroes over the whites.

DeSilva and Robinson[10] have shown that light eyes are on the average

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7 Prentice Reeves, "Rate of Pupilary Dialation and Contraction." Psychological Review, XXV, 330-340, 1918.

8 H. Jeghers, "A Degree and Prevalence of Vitamin A Deficiency in Adults." Am. Med. Association, CIX, 756-761, 1937.

9 H. Helson and J. P. Guilford, op. cit. p. 2.

10 H. R. DeSilva and P. Robinson, "Light Eyes and Glare Sensitivity." Science, LXXXVIII, 299, 1938.

more susceptible to glare than are dark eyes. They did not consider eye color only as lightness and darkness of eyes, but classed the light-eyed group as light gray, blue, and green; and the dark-eyed group as brown, dark brown and dark blue. There were 620 subjects used in the light-eyed group and 618 used in the dark-eyed group.

Bayer[11] has found that fatigue and pain are produced when the eyes are suddenly changed from darkened conditions to brightly lighted conditions but that no pain or fatigue is suffered when the adaptation is changed from lighted conditions to darkened conditions. He observed that the eyes of light-eyed subjects watered more than the eyes of dark-eyed subjects when changed from darkened conditions to brightly lighted conditions. He also found that light-eyed subjects on the average are slower to perceive objects against bright lights.

L. A. S. Wood[12], in a talk to the Safety Council at Benjamin Franklin Hotel, Philadelphia, Pennsylvania, 1937, said:

> Within six years daytime automobile fatalities have decreased 12 per cent. During the same period, night fatalities have increased 37 per cent. During 1936, 37,800 people were killed; 22,000 (over 60 per cent) met death during the hours of darkness, when there is only 20 per cent of the total traffic.

The foregoing facts indicate that night-blindness is perhaps responsible for a large percentage of the fatalities even after defects such as: faulty brakes, inattention, negligence, alcohol, etc. have been accounted for.

The above data signify the importance of good vision in night driving. Jeghers and others have shown that improvements in visual effectiveness can

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11 E. Bayer, "Dark Eyes See Better in the Light." Indust. Psychotechn., X, 207-209, 1933.

12 ________________ "Dark Adaptation in Relation to Avitaminosis A and the Feldman Adaptometer." American Optical Co., 1938.

be made through vitamin A therapy. This hypothesis has been confirmed by the use of the Biophotometer. After improvements in visual effectiveness have been made, the question arises whether the critical ratio between the light-eyed group and the dark-eyed group will remain the same after vitamin A treatment as before treatment.

Guilford, Helson and DeSilva found that it takes more light for a light-eyed subject to detect an object in lighted conditions than for a dark-eyed subject.

According to experimental and statistical evidence, it has also been shown by Helson and Guilford that dark eyes can adapt slightly better than light eyes in darkened conditions but not to an extent to be of statistical importance.

The present investigation is concerned with the determination of the effects of variation in iris pigmentation upon visual adaptation and to further substantiate the findings of others by using a greater number of cases.

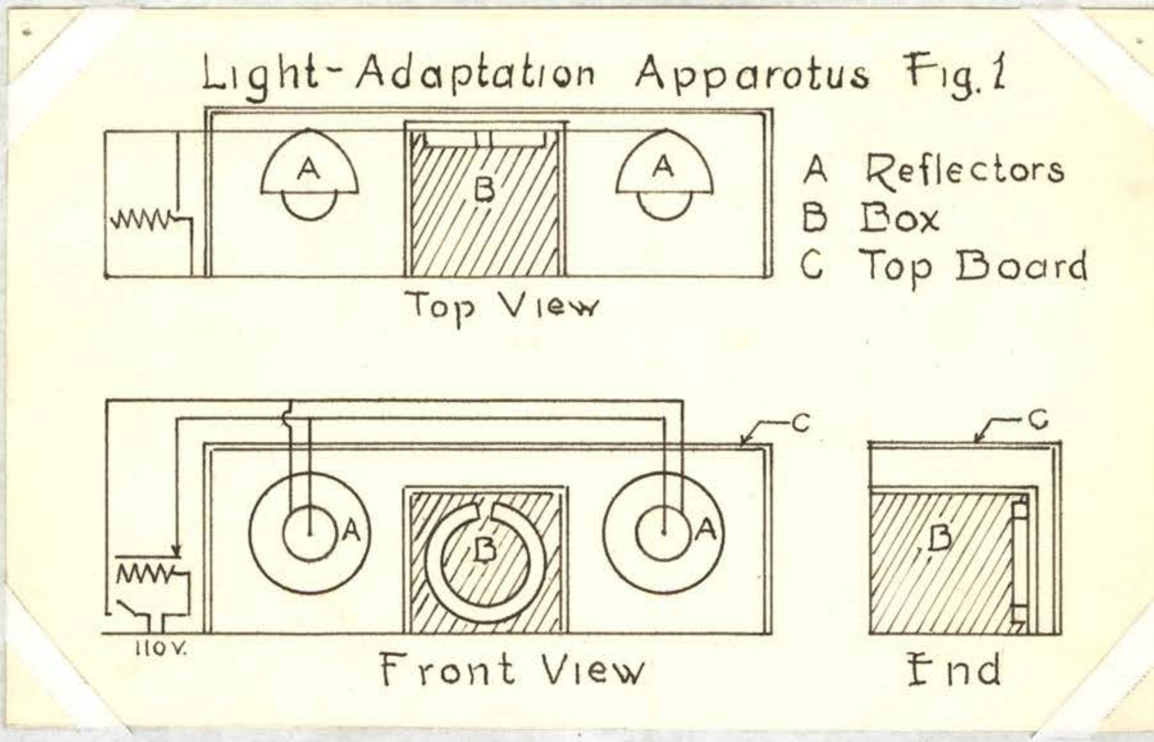
CHAPTER II

METHODS

Apparatus

This experiment was conducted in two adjoining rooms of the Cushing high school, Cushing, Oklahoma. Each room was darkened by heavy black blinds in wooden frames which were constructed to fit each of the inside and outside windows so that all sources of illumination could be controlled.

Light Adaptation:



In the experimental room (32' x 24') the apparatus shown in figure 1 was located. Two reflectors (A) 20 inches apart were placed on a table at one end of the room. Each reflector contains a 300 watt clear incandescent lamp. The light from the lamps is controlled by a variable rheostat on a 110 volt circuit. A box (B), eight inches square and eight inches deep and open at one end, contains a thin metal Landot ring painted white. The inside of the box is painted black. The outside diameter of the ring is seven inches and the inside diameter is five and one-half inches.

Preliminary tests showed that ceiling and floor reflections caused unequal illumination on the ring. To eliminate this, a dark cloth was spread on the floor between the subject and the reflectors and the board (C) was placed over the reflectors. This arrangement resulted in equal illumination around the ring.

Eight and one-half feet directly in front of the reflectors and facing them is a chair on which the subjects sat. This distance was used because the reflectors are set so that the light from them is focused at this point.

Dark Adaptation:

At the opposite end of the experimental room the dark adaptation apparatus is located. It consists of a low dark table with a black back board 24 inches wide and extending upward 30 inches from the far end of the table. In the center of the board is a thin metal Landot ring painted white with the same dimensions as the ring described above. Both rings are supported by a circular track of small black nails.

Facing the ring and 16 feet back is a chair. Hecht, Wald, and others have found this to be the optimal distance for dark adaptation experiments.

Two feet to the right of the chair is an opaque screen 40 inches wide and 36 inches high that projects vertically from the floor. Directly behind the screen is a box 12 inches high which contains four 1½ volt dry cell batteries connected in series which operate a six volt bulb that projects above the box. This bulb is controlled by a variable rheostat and is covered with a translucent paper cone. The position of the box and the screen is kept constant as is the position of the chair for the subject.

A General Electric sight meter for checking the constancy of illumination and a stop watch for determining the adaptation time were also used.

Subjects:

The subjects of this experiment were 32 boys and 58 girls, 12 to 18 years of age, from the junior and senior high school classes. Forty-five of these have light eyes, light blue and blue; and 45 have brown eyes. Subjects with grey and hazel eyes were not used as they can not be placed in either of the above groups.

Procedure:

Before the experiment was performed blinds were constructed and put in the windows, the reflectors were set, and the positions for the reflectors and the subjects' chairs were determined. The Landot rings were made and painted, the low intensity light was set up, and arrangements were made with Dr. R. E. Leatherrock, an oculist of Cushing, to make the visual acuity tests for each subject used in the experiment.

One hundred twenty-eight subjects took the visual acuity test. Ninety of these have acuties of 20/20, and none less than 20/20-1. Thirty-eight subjects were not used because of low acuties.

The experiment was performed during the latter part of April and the first part of May, 1939. During this period four to seven subjects were tested during each experimental period until the 90 had been tested.

As each small group came to the laboratory, they were given instructions. They were shown where the Landot ring was placed for each adaptation. They were instructed that the break in the ring was to be set at different positions corresponding to the hour hand of a clock. The hours 12, 1:30, 3, 4:30, 6, 7:30, 9 and 10:30 were used to eliminate guessing.

For the light adaptation tests the group was placed in the adaptation room in the dark for 20 minutes. Piper[1] has shown that this is sufficient

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1 H. Piper, "Over Dark Adaptation." Zsch. f. Psychol. XXXI, 161-214, 1903. as quoted in Carl Murchison, Outlines of Gen. Experimental psy., 1934, Clark University Press, p. 725.

time for the eyes to adapt themselves to the dark. While the subjects were in the dark room, the 300 watt lamps in the experimental room were adjusted to 25 foot candles of illumination at the approximate point where the subject's eyes were to be. This light was controlled by a variable rheostat and was kept constant throughout the entire experiment.

One at a time the subjects were brought directly from the adaptation room into the experimental room which was totally dark. There was no possibility of any light adaptation before the test began. The subject was then placed in the chair directly in front of the reflectors and facing them, the eyes being in the same plane as the reflectors.

Further instructions were given here. The subjects were told not to blink, squint, nor close their eyes and not to shield their eyes with their hands nor look away as that would delay adaptation, but to look directly into the box for the ring and the position of its break, and to call its position as soon as it could be distinguished. If the subject called out the position of the break correctly the timer said, "All right"; if wrong, the timer said nothing.

The subject was then exposed to 25 foot candles of direct illumination. At the same instant that the light was turned on, a stop watch was started and the time required for correct identification of the Landot break was determined.

After the subjects in each small group had been tested for light adaptation, they were sent back to the adaptation room for five to ten minutes. The room was then illuminated to 15 foot candles.

One at a time they were again brought into the experimental room and seated in the dark adaptation chair. The subject was then exposed to 20 foot candles of illumination.

The lights were switched off with only the low intensity light burning.

This light gives five foot candles at a distance of one inch from the small bulb. This light is behind the screen and is kept constant by a variable rheostat. It allows only .0001 foot candles of illumination on the ring. Adaptation is, therefore, rather slow.

As the lights were switched off, a stop-watch was started and the time in seconds and tenths of seconds for identifying the position of the break in the ring was determined.

CHAPTER III

RESULTS

The results of both groups for light adaptation are shown in tables I and III. Table I shows that there is a mean difference of nearly 10 seconds. The critical ratio of 2.06 in favor of the dark-eyed subjects tells us that the chances are about 980 out of a 1000 that the true difference is greater than zero. This critical ratio is not statistically reliable.[1] The mean of the distribution was used for the computations.

Table three shows a median difference of 2.9 and a critical ratio[2] of .51 in favor of the dark-eyed subjects which tells us that the chances are about 695 out of a 1000 that the true difference between the two groups is greater than zero.

The results of both groups for dark adaptations are shown in tables two and four. Table II, using mean scores, shows there is a difference of only .06 of a second. The critical ratio is only .0147 in favor of the dark-eyed subjects. This tells us that the chances are about 506 out of a 1000 that the true differences between the two groups is greater than zero. This difference is what one would expect if chance alone were the cause.

Table IV, using the median scores, shows a difference of six seconds. The critical ratio of .875 in favor of the dark-eyed subjects tells us that the chances are about 809 out of a 1000 that the true differences between the two groups is greater than zero.

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1 To be statistically reliable, using the mean, the $\dfrac{\text{difference}}{(\text{Sigma}_{M_1}{}^2 + \text{Sigma}_{M_2}{}^2)^{\frac{1}{2}}}$ should be = to 3.

2 To be statistically reliable, using the median, the $\dfrac{\text{difference}}{(\text{Sigma}_{Mdn_1}{}^2 + \text{Sigma}_{Mdn_2}{}^2)^{\frac{1}{2}}}$ should be = to 3.

TABLE I

From dark adaptation to light adaptation

	Light eyes	Dark eyes
Number	45	45
Mean in seconds	29.26	19.93
Standard error	27.6	13.71
Standard error of the Mean	4.1	2.04

Standard error of the difference of M_1 M_2 = 4.58

Difference/sigma diff. or critical ratio = 2.06

TABLE II

From light adaptation to dark adaptation

	Light eyes	Dark eyes
Number	45	45
Mean in seconds	33.7	33.64
Standard error	15.99	22.2
Standard error of the Mean	2.59	3.31

Standard error of the difference of M_1 M_2 = 4.07

Difference/sigma diff. or critical ratio = .0147

TABLE III

From dark adaptation to light adaptation

	Light eyes	Dark eyes
Number	45	45
Median in seconds	21.4	18.5
Standard error of the Mdn.	5.13	2.55

$$\text{Difference}/(\text{sigma mdn}_1{}^2 + \text{sigma mdn}_2{}^2)^{\frac{1}{2}} = .51$$

TABLE IV

From light adaptation to dark adaptation

	Light eyes	Dark eyes
Number	45	45
Median in seconds	31	25
Standard error of the Mdn.	5.24	4.14

$$\text{Difference}/(\text{sigma mdn}_1{}^2 + \text{sigma mdn}_2{}^2)^{\frac{1}{2}} = .875$$

For light adaptation the critical ratio, computed from the means, of 2.06 is greater than the ratio of .51 which is computed from the medians. This difference is probably due to the last three light-eyed subjects (appendix p. 17) who are extremely slow to adapt. The forty-third and forty-fourth subjects have very light eyes and the last one has many characteristics of an albino. These extreme cases would cause a significant variation in the mean, while they would not alter the value of the median.

For dark adaptation the critical ratio, computed from the means, of .0147 is less than the critical ratio of .875 which is computed from the medians. This gives a reversal of the critical ratios established for light adaptation. This difference is probably due to the last seven dark-eyed subjects (appendix p. 17) who are slower than the corresponding seven light-eyed subjects. These seven who are slow to adapt would cause a significant variation in the mean, while they would not alter the value of the median.

When comparisons of the ten fastest and the ten slowest subjects in each group are made (appendix p. 18) for light and dark adaptations, no relation can be established between slow adaptations in darkened conditions and slow adaptations in lighted conditions. No relationship is found when rapid adaptation in lighted conditions is compared with rapid adaptation in darkened conditions.

CHAPTER IV

SUMMARY AND CONCLUSIONS

Forty-five dark-eyed subjects and 45 light-eyed subjects of high school age were dark adapted for 20 minutes, then subjected to 25 foot candles of direct light. The time in seconds required to identify the opening in a white Landot ring was determined. They were then light adapted after which they were exposed to darkened conditions. The time in seconds required to identify the opening in the Landot ring was determined.

The results of this experiment are treated by two different methods. When the mean scores are used a critical ratio of 2.06 in favor of the dark-eyed subjects is found for light adaptation, and a critical ratio of .0147 in favor of the dark-eyed group for dark adaptation.

When the median scores are used a critical ratio of .51 in favor of the dark-eyed group is found for light adaptation and a critical ratio of .875 in favor of the dark-eyed group for dark adaptation.

These data suggest the following conclusions:

1. When the data are treated by the mean, a fairly reliable ratio is found in favor of the dark-eyed subjects over the light-eyed subjects in light adaptation and only a chance difference in dark adaptation.

2. When the data are treated by the median, an unreliable ratio is found in favor of the dark-eyed subjects over the light-eyed subjects in light adaptation and only a slightly reliable ratio in favor of the dark-eyed subjects over the light-eyed subjects in dark adaptation.

3. The results obtained depend on the method of treating the data.

The data also lead to the following implications:

While not statistically reliable, the critical ratios are in the direction of the dark-eyed subjects in both dark and light adaptation, but to a greater extent in light adaptation. These critical ratios are so small that they are hardly more than chance differences.

Extremely light-eyed subjects show slowness to adapt as compared with dark-eyed subjects in bright lights.

Slowness to adapt in the dark is slightly more common among the dark-eyed subjects.

More cases would probably determine the outcome since a few extreme cases modify the mean based on a small number of cases more than does the median.

The results of this experiment are equivocal. If table I is used, the conclusion is that dark-eyed subjects adapt more rapidly. If table II is used, the conclusion is that chance determines whether dark or light-eyed subjects adapt more rapidly. If tables III and IV are used, similar equivocations accrue.

APPENDIX

Chronological Order of Data

Adaptation time in Seconds

Light-eyed subjects: Light to Dark	Light-eyed subjects: Dark to Light	Dark-eyed subjects: Light to Dark	Dark-eyed subjects: Dark to Light
8	3	3	3
10	4	9	3.2
11	4	12.2	4
13	4.5	13.5	4
13	4.6	15	4.8
14	4.8	16	5
15	5	17.2	5
16	6.5	17.6	5
16.5	6.8	18.2	5.4
17	9	18.4	6
19	9.2	18.4	7
20	11	18.6	7.5
21.2	11	18.8	8.5
23.4	13	20	9
24	13	20	9
26.8	13.5	22	9
27	16	22.8	11.8
28	16.3	23	12
29	17.4	23	15
29.4	18	23.2	17
30	18	24	17.8
30	20	24.6	18
31	21.4	25	18.5
32.2	24	26	19
33	26	28.8	19
34	29	29	19
36.5	30	30	20
37.5	31	32	22
38	31.2	35	25
40	31.6	36.5	25
41	32	37	26
41	32.6	40	27
43	35	40	28
45	43.5	40.8	30
46	45	41.5	31
47.4	47	44	31.5
48	49	45	33
48	49	51	33
49	52	65	33.5
50	52	65	36
52	60	65	38
58	68	71	38.2
65	87	71.2	50
66.2	90	72	50
95	145	125	55

APPENDIX

Data of the Entire Experiment as Actually Performed

Light-eyed subjects: Light to Dark	Light-eyed subjects: Dark to Light	Dark-eyed subjects: Light to Dark	Dark-eyed subjects: Dark to Light
20	31	3	9
16	45	40	25
48	24	29	33
43	13.5	23	19
15	49	22	7
13	16	45	5
13	9	41.5	11.8
10	20	18.4	17
17	32.6	44	18
31	13	25	7.5
40	17.4	24	8.5
14	52	65	5.4
29	18	65	5
41	49	28.8	6
29.4	31.6	65	50
46	11	30	18.5
34	16.5	125	17.8
30	35	25	31
50	52	40	55
37.5	29	18.4	15
33	31.2	51	33
58	90	24.6	19
65	145	20	27
27	26	40.8	58
36.5	13	71	22
19	18	71.2	12
41	43.5	9	38.2
11	3	12.2	4.8
26.8	6.5	72	5.2
16.5	4	17.6	50
48	4.8	18.8	35.5
24	9.2	23	36
52	32	32	26
45	30	23.2	30
38	21.4	20	20
30	68	22.8	31.5
8	6.8	17.2	25
47.4	5	36.5	28
32.2	4.5	18.2	4
21.2	4.6	15	19
95	4	18.6	3
66.2	11	16	9
23.4	47	26	9
28	60	37	5
49	87	13.5	4

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