ON VARIATION OF ACCOMMODATIVE NEAR POINT BY GLARE

KAORU YAGASAKI

Department of Ophthalmology, Yamaguchi Medical School, Ube
Director: Prof. Shyozo Oishi

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The problem of glare is important in connection with asthenopia. The majority of experimental research in glare has been done on decline of visual acuity caused by glare in distant vision, and only a few reports have been published on glare in near vision. In Japan, Kubo[1] is the only one who conducted a continuous measurement of near point, describing their remarkable recession in the beginning of the measurements. He stated that glare was responsible for the recession.

In as much as it seemed probable that glare might also occur in the case of near vision, the author studied on the receding of near point which was partly discovered by Kubo[1], and tried to find out whether or not its recession was related to glare. The author also studied the cause of the recession and then attempted experiments on glare by using four sheets of paper, each having different reflection rate, on the relation between glare and the accommodator, on the glare caused by a fluorescent light, and on the fatigue of accommodator.

VARIATION OF ACCOMMODATIVE NEAR POINT CAUSED BY THE DIFFERENCE OF AN ADAPTED CONDITION

Experiment I

Equipment of Experiment: See Fig. 1.

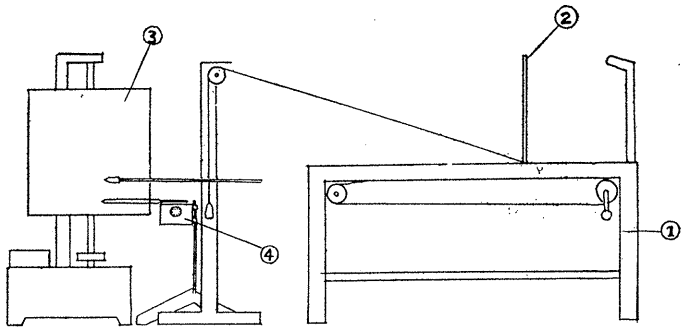
Object: 30mm × 15mm of Ishihara's test chart for near vision was pasted on a black paper (20cm × 15cm, reflection rate 7%) and was placed in front of the right eye.

Illumination: 500 w. and 200 w. tungusten filament light were illuminated from the right back, 45 degrees above.

Personnel tested: The author himself (30 years old, R.V. = 0.5(1.0 × −0.75D)) and three others (one student and two interns) having good visual acuity.

Method of Experiment: Experiments were conducted early in the morning and just after nap-time when those tested had not used their eyes excessively, because mental and physical condition have influence on the measurement of the near point. No measurement was therefore made when they felt fatigue. Before the measurement was started, the eyes of the tested people were adapted

to the dark for 30 minutes, 5 minutes and 15 minutes, respectively. The description of the method for measurement of near point is omitted here, for its account is found in the common literature.



1) Ishihara's nearpointmeter
2) Object
3) Kymographion
4) Chronometer

Fig.1. Equipment of experiment.

Result of Experiment: The data of the experiment is depicted in Fig.2 and Fig.3. The outline is summarized as follows: At first the near point approached to and beyond the nearest value until the nearest value of the measurement was reached. The details are shown in Table I.

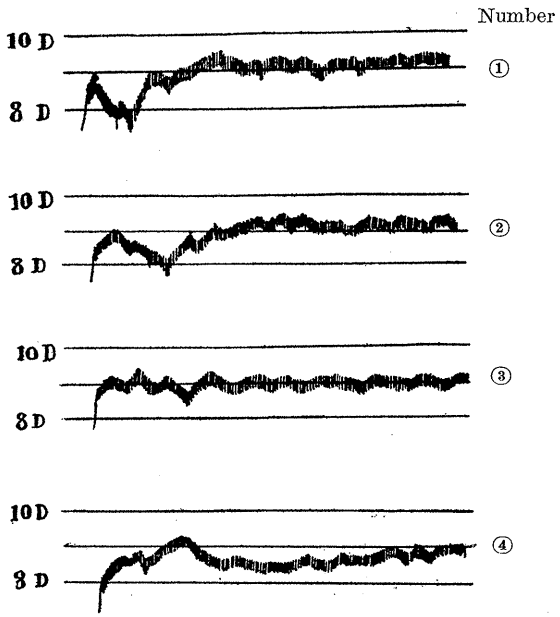


Fig.2. Dark adaptated eye.

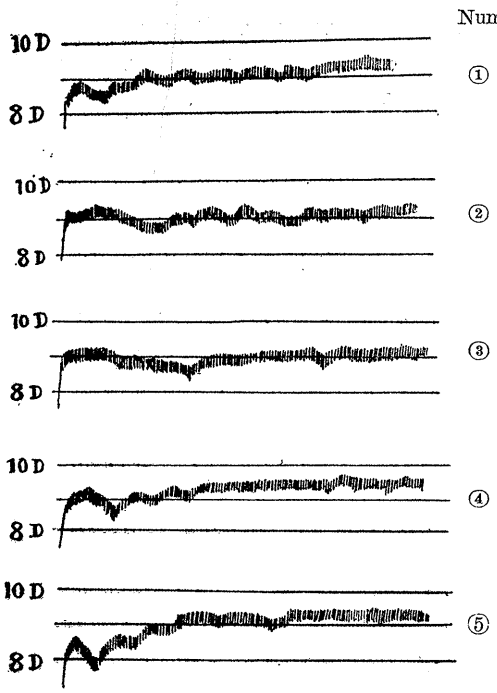


Fig. 3. Light adaptated eye.

TABLE I

Number	1	2	3	4	1	2	8	4	5
Adaptation	dark adaptation				light adaptation				
					500Lx 5min.	200Lx 5min.	100Lx 5min.	200Lx 5min,	50Lx 5min.
Surfaceillumin.	500Lx	200	100	50	500	200	100	500	500
Nearest value in the beginn.	D 8.8	8.8	8.9	9.0	8.5	9.0	8.8	8.8	8.3
Farthest value	D 7.5	7.8	8.1	8.2	8.3	8.5	8.4	8.3	7.8
Nearest value	D 9.0	9.0	8.9	8.7	9.1	9.0	8.8	9.3	9.1
Grade gets far	D 1.5	1.2	0.8	0.5	0.8	0.5	0.4	1.0	1.3
Time gets far	sec 39	75	84	165	36	87	116	45	33

Summary:

(1) In case of eyes adapted to the dark:

a) The degree of the recession of the near point was proportional to the rise in the illumination of the object surface.

b) The time required for reaching the farthest near point was shortened.

c) The nearest near point referred to the illumination of the object surface. At 500 Lux the nearest was obtained while at 50 Lux the farthest was attained.

(2) In case of eyes adapted to the light:

a) The degree of receding was less than that of the dark-adapted eyes without regard to the illumination of the surface of object.

b) The time required before near point receded the farthest was longer than in the dark-adapted eyes. If adaptation and the object surface illumination are adjusted in constant proportion, the elongation of the near point was remarkable in proportion to the lowering of the object surface illumination.

c) Regardless of the object surface illumination, the degree of the approach near point was more pronounced than in the case of dark-adapted eyes.

Comparison Experiment: In the measurements mentioned above the receding of the near point occurred within approximately 50 seconds after the measurements were started.

Experiment II

The variation of the near point in Experiment I was observed by regulating the amount of light going into the eye ball by means of a glass which has a round hole.

Equipment of Experiment: An oculoergograph, exactly the same type which was used in Experiment I. Glasses with a round hole of 0.5, 1, and 2mm in diameter were prepared, and were placed in front of the eye. Illumination was fixed constantly at 500 Lux.

Method of Experiment: Exatly the same as that of Experiment I. Results of Experiment: See Fig. 4.

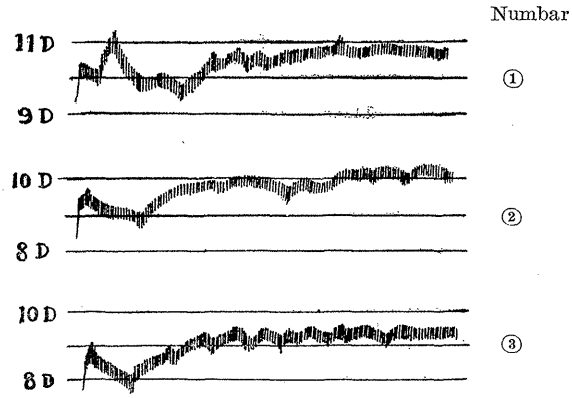


Fig. 4. With round hole.

Summary: The smaller the diameter of the hole of the glass, the nearer was the first nearest near point, and the degree of receding decreased. The nearest

near point receded. The time required for the near point to recede the farthest was prolonged.

Experiment III

Through this experiment, the author tried to find out the causes of the variation of the near point.

Equipment of Experiment: Disks having 4mm diameter with a white paper of 69% reflection rate were made, and they were arranged in radial form on white paper of 84% reflection rate (size; 15cm × 20cm); it was put up 12 centimeters before the eye. The appearance and disappearance of scotoma was recorded on a kymographion by use of electro-magnet. The method of illumination was the same as that used in Experiment I. Illumination was fixed at 50, 200, 500, and 2000 Lux.

Method of Experiment: After being adapted to the dark for 30 minutes, a button for the magnet was pushed during the time when scotoma appeared, and in this way the length of time that the scotoma appeared was recorded on the kymographion.

Results of Experiment: Table II shows a record of appearance and disappearance of transitory scotoma. At 2000 Lux, the object surface could not be recognized at the time illumination was started, due to feeling of glare.

Summary: From this experiment, it was learned that the variation of the near point was partly caused by the appearance of the scotoma due to glare.

TABLE II

Illumination	Time till the scotom were seen 2)	Duration of the scotom 3)
2000 Lux	1. sec	24. sec
500 Lux	2.5 sec	16.5 sec
200 Lux	3.8 sec	11.2 sec
50 Lux	Scotom were not seen	

1) In the beginning (about 3 seconds) object were can not seen by grare.
2), 3) shown as average

Experiment IV

From Experiment III. it was known that a cause of the variation of the near point was the appearance of transitory scotoma by glare; however, it was not a clear explanation of causes, because scotoma disappeared very quickly, while on the other hand, the near point that had once detached required a considerable time to get back. The author, therefore, made the following experiment on the so-called "glare by after-image" phenomenon.

Equipments of Experiment: Backgrounds and objects consisted of the following;

	Backgrounds	Objects
1)	White	Red disk. 1 cm diameter.
2)	Black	White disk, 1 cm diameter.
3)	White	Black disk, 1 cm diameter.

The size of backgrounds was 20cm × 15cm each, and was placed 12cm before the right eye. Illumination was fixed at 50, 100, 200. and 500 Lux. The equipment for recording after-image was the same type that was used in Experiment III.

Method of Experiment: Experiment was started 30 minutes after adaptation to the dark. The button was pushed and released according to appearance and disappearance of the after-image. This operation was continued until the after-image no longer appeared. Thus, the kymographion recorded how many times the after-image appeared.

Results of Experiment: See Fig. 5.

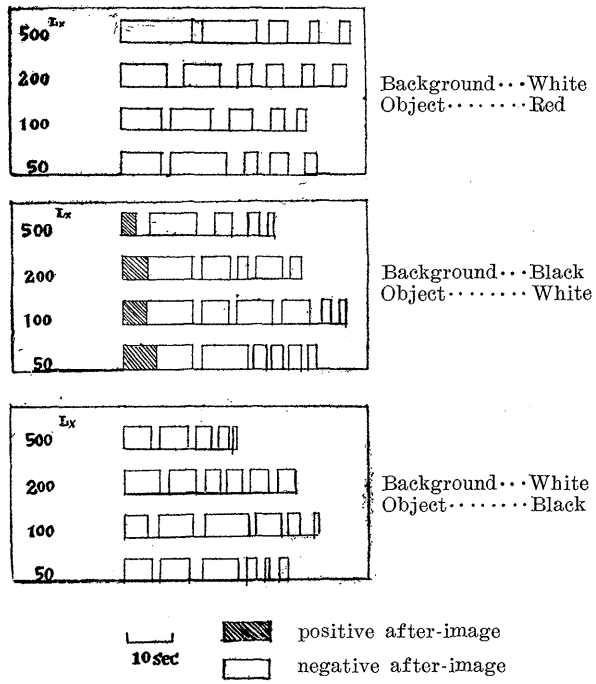


Fig. 5. After-image

Summary: The phenomenon that the process became convalescent after the near point had made the farthest recession can be understood on the basis of the appearance of the after-image.

Discussion: As mentioned above, the location of the near point was variable

when the accommodative near point was continuously measured. Then, the author desired that the distance between the near points on both sides of the farthest point should be defined as "Glare Effect". Reasons for this are: 1) Dark-adapted eyes had more remarkable glare effect than light-adapted eyes. 2) In case of dark-adapted eyes, the higher the object surface illumination, the earlier and sharper this trough appeared. 3) The higher the object surface illumination, the shorter was the time needed for the near point after it had showed the farthest value. When the above results are compared with those made previously, there is something in common between them. That is that disturbances of vision occurred just after dark adaptation was changed to light adaptation. This disturcance continued for a while, and the higher the illumination, the severer the disturbance was. The author, therefore, believed that the disturbances of vision in his experiments were caused by glare.

It is recognized from Experiment III and IV, that scotoma by glare in the beginning, and the after-image, made clear the mechanism of the near point. It is a natural result that there are time lags between the results of Experiment I and those of Experiment III, IV.

On Glare Due to Different Grade of Papers, and Fatigue of Accommodator

Experiment V

Considering asthenopia, object surface illumination is not always equal, even though it is illuminated by the same source of light from the same direction. Therefore, there is a possible difference in appearance of asthenopia. In this experiment the author studied glare due to different grades of paper

Equipment of Experiment: An oculoergograph, the same type which was used in Experiment I, Chapter I. Objects were made with four different grade paper as shown on Table III, and they were printed with five black Katakana-Letters of No.8 type. The Pulfurich's photometer were used to measure the reflection rate. The reflection rate was expressed in percentage against that of the barium sulfate surface, which was given the value of 100%. The reflection rate of each paper is shown in Table II.

Table III

Reflection rate of each paper

Art	A	B	C	D
Colour	white	light yellow	white	white
Reflection rate	95%	79%	84%	69%

(A) Thin art paper, (B) light yellow paper which was commonly used by publishers for publication of complete books, etc., (C) western paper of good

quality, (D) regular paper, quality of which was similar to news papers.

Method of Experiment: Object surface illumination was fixed constantly at 500 Lux. The measurement was done for 25 minutes. The rest was the same as Experiment I.

Results of Experiment: In general, the results were similar to those obtained in Experiment I. However, the variation had a tendency to appear on the left owing to illumination, 500 Lux, and use of high reflection rate papers. The results are lumped together in Table IV.

TABLE IV

Art	Nearest value in the beginn.	Farthest value	Time gets far	Nearest value
A	8.6 D	7.7 D	15 sec	9.3 D
B	8.7 D	8.3 D	21 sec	9.3 D
C	8.6 D	8.0 D	15 sec	9.3 D
D	8.8 D	8.1 D	18 sec	9.0 D

Summary: 1) Comparison with the results of Experiment I, the time required to show the farthest point was reduced. Further the higher the reflection rate of paper, the shorter the time was. 2) The higher the reflection rate of paper, the more the intensity of glare effect appeared. 3) In case of high reflection rate paper, the location of the nearest value during the measurement was nearer than that of low reflection rate paper. 4) In case of high reflection rate paper, the location of the near point value observed 25 minutes after was farther than that of the low reflection rate paper. 5) The value of the near point was the nearest with (B), and the farthest with (A) and (C). 6) It was believed that (B) was the best for prevention of fatigue of accommodator.

Experiment VI

How is glare varied by changing the distance between the light source and the object surface to adjust the amount of light going into the eye directly?

The following equation from illumination engineering can be used:

$$E = \frac{I}{L^2} \mathrm{Cos}\theta$$

E ····· Intensity of illumination, horizontal.
I ····· Intensity of light.
L ····· Distance between light source and object surface.
θ ····· Angle of incidence.

It is found that proper distances are 80 cm with (A), 67 cm with (B), 72 cm with (C), and 60 cm with (D).

Equipment and Method of Experiment: The same as those used in Experiment V.

Results of Experiment: See Table V.

TABLE V

Art	Nearest value in the begin.	Time gets far	Farthest value	Nearest value
A	8.5 D	13 sec	7.4 D	9.6 D
B	8.6 D	15 sec	7.5 D	9.6 D
C	8.5 D	15 sec	7.5 D	9.6 D
D	8.5 D	18 sec	7.6 D	9.5 D

Summary: There is almost the same glare effect regardless of reflection rate of papers, if the object surface illumination is equally adjusted by means of changing the distance between the light source and the object.

Experiment VII

What is the result in case of a high object surface illumination, such as 750 Lux and 3000 Lux?

Method of Experiment: Object surface illumination; 750 Lux and 3000 Lux. Paper (B) was used. The rest was the same as in Experiment V.

Results of Experiment: At 750 Lux the nearest value during the measurement was bigger than that at 500 Lux, however at 3000 Lux the nearest value appeared as if it were bigger due to a wide amplitude of variation.

Summary: In conclusion, individual difference and the reflection rate of object have a strong relation to glare effect. The upper limit, below which people do not feel glare, must be around 500 Lux.

Discussion: As Helmholtz's theory on fatigue of accommodator means fatigue of ciliary muscle, it is said in physiology of the muscle that, in the beginning, the muscle gradually increases its contraction by stimulus. However, there is a step phenomenon, and contraction, decrease if stimulus is continued more and more. It seems that this fact is similar to a gradual receding of near point. For the study of fatigue of the accommodator, it is important to consider, in addition to the above, fatigue of retina and cerebral center.

In tests by high illumination, once the near point gets near except for glare obsrved in the beginning of the test it seems advantageous for accommodation; however, the contiguity does not last long, and soon becomes far again. For the purpose of obtaining a necessary and sufficient illumination for reading books, it is necessary to examine the continuity of accommodation, in addition to examining of the location of near point.

ON GLARE, AND FATIGUE OF ACCOMMODATOR CAUSED BY FLUORESCENT LIGHT ILLUMINATION

An experiment was conducted on glare, and fatigue of accommodator caused

by fluorescent light being widely used now a days.

Equipment and Method of Experiment: Light source; 2～20 watts day light type fluorescent lamps. The rest was the same as those used in Experiment V.

Results of Experiment: See Table VI.

Table VI

Art	Nearest value in the begin.	Farthest value	Time gets far	Nearest value	Grade gets far	Nearpoint after 25 min.
	D	D	sec	D	D	D
A	9.2	7.5	9	9.5	2.0	8.0
B	9.1	7.7	12	9.4	1.7	8.4
C	8.8	7.4	12	9.2	1.8	8.1
D	8.7	7.7	15	9.4	1.7	8.3

Summary: 1) There was no difference in glare effect between this and Experiment V. 2) The time it took for the near point to get to the fartheest point was shorter. 3) There was no difference in nearest values during the measurements, between this experiment and Experiment V. 4) The location of near point observed 25 minutes after the experiment was started was the nearest with (B), and was the farthest with (A) and (D).

Discussion: The reflection rate is possibly varied according to the wave length of the light. The author measured, by use of Purfrich's photometer, several reflection rates; then some different filters were attatched to the source of light. The results were shown in Table VII. Some fluorescent lights developed recently are effecting good results to the eye, however, some others are causing disturbances of the eye. From the experiment explained in this chapter, no difference is recognized in fatigue of accommodator, regardless of the type of illuminationday light or fluorescent light. Efficiency of labor is effected not only by fatigue of the eye also by circumstances and condition of mind and body, therefore the above mentioned results should not be applied to measure efficiency of labor.

Table VII

＃＃ \ ＃	K_1	K_2	K_3	K_4	K_5	K_6
A	91%	93%	95%	97%	98%	98%
B	79	80	79	78	76	75
C	85	84	84	83	79	77
D	75	70	69	60	58	57

＃ Art of filter ＃＃ Art of paper

An addition: On Glare

There is no text-book giving a clear definition on glare. However, the classification of glare has been made by the society of illumination, and by Mr. Awaji.

The author discussed the subect from a different view point, and wishes to add (1) glare without feeling of glare to (2) glare with feeling of glare, which is defined in the above classification.

Summary and Conclusion

The author measured by use of oculoergograph the accommodative near point of dark-adapted eyes with light adapted to the object surface for 5 minutes and 15 minutes each; light adapted to lower and higher intensity of illumination than the object surface, for 5 minutes; at 50, 100, 200, and 500 Lux for 5 minutes in a series, and obtained the following results:

1) The accommodative near point became near in the beginning, then got far, then became near again, and at last reached to the nearest point.

2) In the beginning, the higher the intensity of illumination, the lower the intensity of contiguity.

3) The higher the intensity of illumination, the earlier the farthest value appeared.

4) These variations could be caused by glare.

5) We tried to explain these variations were caused by scotoma which came from glare and after-image.

By using objects printed on four different reflection rate papers, near point curves were drown and the following results were obtained:

1) At 500 Lux, the higher the reflaction rate, the more glare effect and contiguity appeared.

2) As to the near point after 25 minutes, the higher the reflection rate, the farther the near point was located. On the contrary, the lower the reflection rate, the nearer the near point was located.

3) If the object surface illumination is properly adjusted, the quality of paper will scarcely make any difference of the above effects.

4) Therefore, utilization of the object surface illumination as a standard will be convenient for the study of illumination in comparison with illumination results.

Tests at the high intensity of illumination:

5) At 750 Lux, the location of near point was nearer than that at above illumination, however, it receded after 25 minutes.

6) At 3000 Lux, the location of the near point was nearer than that at 750 Lux, and it also receded 25 minutes after.

7) From these results, if we want to obtain a proper illumination for reading books, doing close work ect., it is more important to examine the time

required for accommodation than examinig the location of accommodation than examining the location of accommodative near point.

Under a day light type fluorescent lamp, the accommative near point was measured with oculoergograph at 500 Lux, for 25 minutes continuously, and the following results were obtained:

1) There was no difference in glare in either case, fluorescent or tungusten lamp illumination.

2) Neither was there any difference in fatigue of accommodator in eithor case.

The author added to the classification of glare discussed from his new point of view.

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References

1) Kubo, F.: On accommodation and adaptation. *Acta Sco. ophthalm.* jap., **58**, 373–377, 1954. (in Japanese)