COMPARISON OF THE INFLUENCES OF VISUAL ANGLE AND OF VARIATION OF PUPILLARY DIAMETER SEEN IN CFF LDR RELATION

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Introduction

There have been many studies on the variation of pupillary diameter affected by the luminance of light, while it seems that comparatively few studies on the matter with relation to CFF have been made.

Bartley (1937) concluded that the sensation of flicker depends on an alternation of *on* and *off* responses in firing of impulses. Alpern and Sugiyama (1961), in their study on photic driving, concluded that the facilitation or inhibition seen in CFF level depends on the firing characteristics of visual cells. The above mentioned *facilitation or inhibition* was used as a device to investigate the process of flicker sensation in a sense. The present author beleives that flicker sensation must correspond with this firing mechanism either in the fibers or in the cells, though Alpern and Sugiyama indicated that precisely what these cells are and where they may bo found are still unknown. What they have proposed is that their results are an unequivocal evidence that the fusion of intermittent lights and that Talbot luminance of intermittent lights are not determined by photo-chemical events as is proposed in the theory of Hecht (1933, 1936) or Jahn (1946). Results made dy Alpern and Sugiyama seem to be supported by those mabe by Grusser and Creutzfeldt (1957) or by DeValois (1958) who found that there is a direct relation between the firing frequency of cells (retinal ganglion cells, lateral geniculate cells or cells in striate cortex in the visual system of the cat) and the rate of stimulation of the retina. Namely, as stimulation rate increases the average frequency of firing attains at its maximum and then begins to fall as CFF is approached.

On the other hand, concerning the Stiles-Crawford effect, Alpern and Benson (1953) have shown that the effect is the same whether it is measured by the pupillary diameter or by the apparent brightness and concluded that probably the same receptors are acting in both cases.

With these conclusions, the author assumed that CFF level may be influenced only by luminance level and probably not by the pupillary diameter at a cartain condition and LDR

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tendency may not be so greatly affected by the luminance. With this assumption the author tries to investigate the mechanism of flicker sensation.

Method

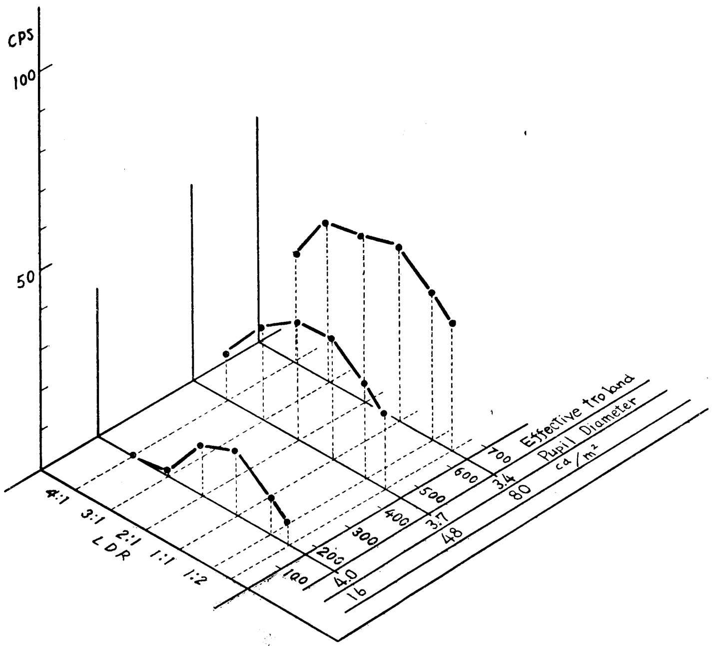
A neon tube type of flicker apparatus, which can control the brightness of light as well as the light-dark ratio from 4 : 1 to 1 : 2.5 (six steps), was used. Three steps of luminance of light, which are (1) 80 cd./sq. m., (2) 48 cd./sq. m., and (3) 16 cd./sq. m. with the visual angle constantly 62' throughout the first experiment, were used. These three levels of luminance make each pupillary diameter different. They are as follows in this particular condition:

(1) 80 cd./sq. m. ……… 3.4 m/m
(2) 48 cd./sq. m. ……… 3.7 m/m
(3) 16 cd./sq. m. ……… 4.0 m/m

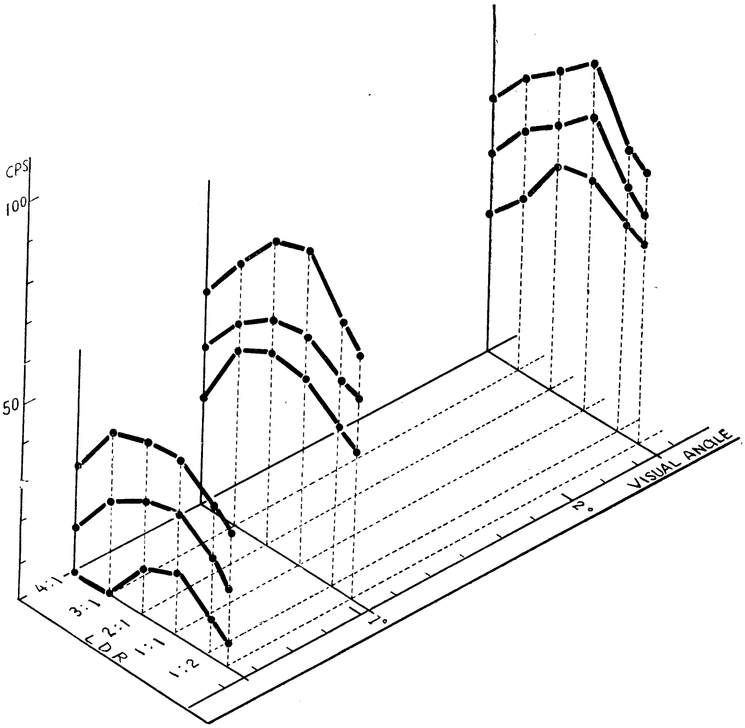
The second experiment was administered with the use of variable visual angles which are (1) 26', (2) 62', and (3) 144' and the same three different steps of luminance as in the first experiment were used. Three young adults with normal vision assisted the experiments as observers.

Results

Figure 1 was obtained from the first experiment. At these three levels of luminance, the relationships between CFF and LDR are almost symmetrical. Always at LDR=1 : 1,



(Figure 1)

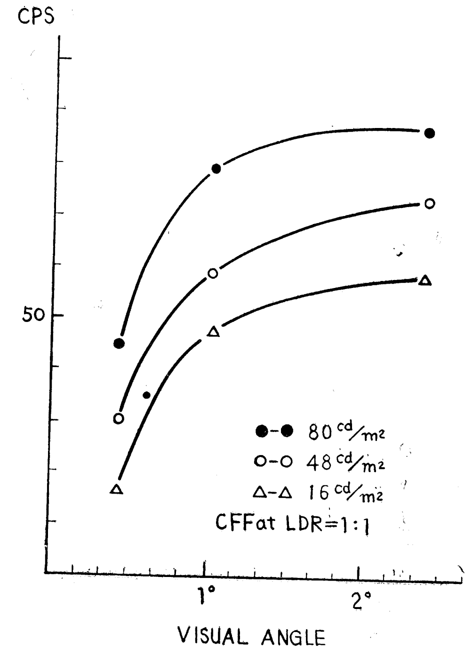


(Figure 2)

the highest CFF level could be observed, regardless of the amount of light incoming to the sense organ, and as the light portion in a cycle either increases or decreases, CFF invariably decreases. This symmetrical tendency of CFF-LDR seems to have nothing to do with luminance used in the experiment, except luminance influence upon the degree of CFF.

In order to investigate the relationship between the visual angle and CFF-LDR, the second experiment was administered and Figure 2 shows the results.

The upper curves show CFF-LDR relations at three different degrees of visual angles with the luminance of 80 cd./sq. m., the middle curves show the same relations with 48 cd./sq.m. and the lower curves with 16 cd./sq. m. The obvious fact shown in this experiment is that CFF is related with luminance and the increment or decrement of light portion in a cycle is not influenced either by visual angle used or by the luminance levels in this experimental condition. However, the reeationship between CFF and the



(Figure 3)

visual angle seen at LDR=1 : 1 is not of a linear fashion as seen in Figure 3. The same relations could be found at other LDRs. It seems that the curves approach to the plateau as the visual angle increses.

These results from two experiments seem to indicate essentially the same thing. That is, CFF is dependent on luminance and CFF-LDR relationship is the same throughout all the conditions used in the experiment. Thus, we may be able to conclude that CFF-LDR relations, (that is, the the relations that, as light portion in a cycle increases or decreases, CFF always decreases and the maximum CFF could be found always when the LDR is one to one) are independent of luminance of light, though the levels differ at each level of luminance.

Discussion

In this study, at the first step of experiment, it was aimed to find some characteristics of the following relations:

(a) Luminance and pupillary diameter
(b) Pupillary diameter and retinal illumination level
(c) Retinal illumination level and CFF-LDR

by the threshold measurement of light which has the following characteristics:

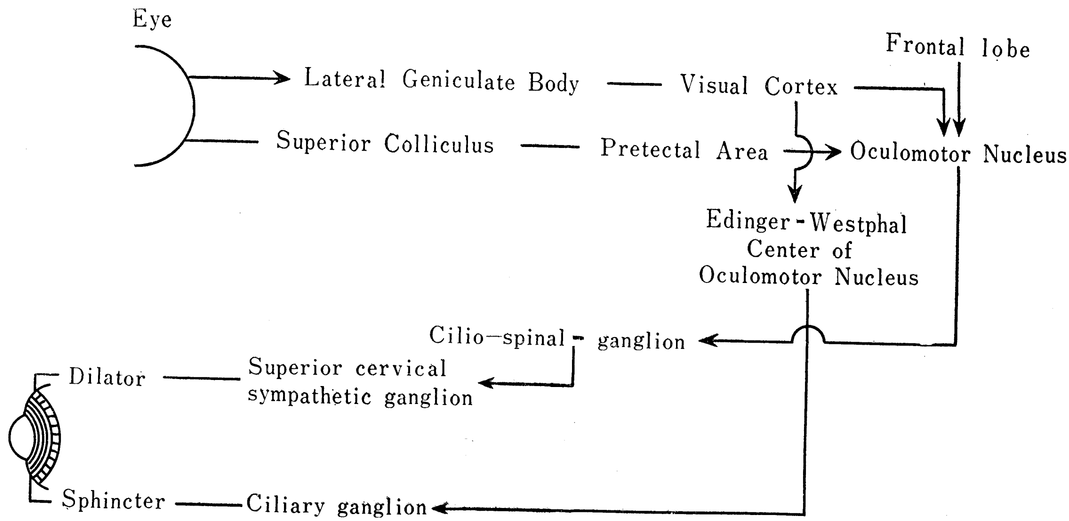
(1) Light was successively given (pulsing light)
(2) LDR was changed: namely, light portion increased or decreased in a cycle.
(3) Luminance of light was changed.
(4) Visual angle was fixed.

At (a), we can assume that physical characteristics of light stimulates the eye and the pupil responds to this in a fashion of dilating or contracting according only to luminance. At (b), this determined diameter (or actually the area) determines the amount of light incoming to the receptor. This also determines the areas on the retina which is activated by the light at (c), if we neglect the function of lens, vitreous body, etc. At (c), the actual activating mechanism is still under the investigation. Of course photo-chemical reaction must work at a certain level of visual processes, but as mentioned before, it is difficuft to say that flicker sensation is determined only at photo-chemical level. The problem still remains unsolved. Especially at (a) and (b), the process indicated seems to be logical but the following facts seem to be obvious.

The pupillary reflex is determined, as far as we know, by the following relations seen in Figure 4.

Either in case of dilating pupil or in case of contracting pupil, these reflective action of pupil is determined by the flow of impulses in the central nervous system, though in each case the different pathway is used.

This may mean that response of pupil is not determined *directly* by the characteristics of light: namely, so far there seems to be no short-cut circuit from the receptor of light to the action of ciliary muscles which determines the pupil diameter. Therefore, we may



(Figure 4) The sphincter arc is as follows: From Edinger-Westphal center, the path passes along the oculomotor nerve to the ciliary ganglion and from there the short ciliary nerves to the sphincter muscle fibers of the iris. Cortical influences are given at Edinger-Westphal center. The dilator arc is more complex. Both the influences from the frontal lobe and visual area of cortex go through midbrain center in the oculomotor nucleus. The dilator pathway leads to the inferior ciliospinal center and next passes the superior cervical sympathetic ganglion. The pathway passes to the radial muscle fibers of the iris. There may be possibility that the superior cervical sympathetic ganglion and the ciliary ganglion are connected, though its existence and function are unknown.

be able to say that radiation energy entering the eye stimulates the receptor and the impulses fired by this and transmitted through the above mentioned terminals and leaving some effects to some of these terminals (another impulses begin to flow, and sometimes these are the beginning of association function) and finally the pupillary diameter is determined. And thus determined pupil size restricts the incoming amount of information.

Since this is a feedback mechanism, it must be assumed that there is an oscillation in output which is commonly found in the case of pupillary size. However. by a supprising capacity of adaptation function, the pupil diameter becomes fixed, as time passes. This is one factor which was unable to be controlled in this experiment. By the reason which was indicated above, especially the (b) becomes the secondary factor which influences the central nervous system in this experiment.

Therefore, the second experiment was designed to investigate the influence of luminance with variable visual angle. Factor (4) was not the same as in the first experiment, but other factors are the same. In this case, the pupillary diameter is neglected. However, it is technically difficult to neglect completely the changes of pupillary diameter by luminance and whether or not this is the reason why the author obtained the similar tendency in Figure 1 and 2 is not decisive enough. Even though we assume there is a definite influence of the pupillary diameter, the influence of luminance seems to appear mainly in CFF and not in LDR tendency, because we can see the similar tendencies throughout all

Figure 4 was modified from the figure made by Bartley. (1951)

the conditions, as seen in Figure 2.

The author thinks that the main influential factor to CFF is luminance, as has been thought, and this determines CFF level whatever the LDSs are in this experimental condition.

As Bartley thought, if we assume LDR is, in a sense, proportional to the firing impulses or to the firing frequency in the cells as proposed by Grusser and Creutzfeldt, by DeValois, and by Alpern and Sugiyama, the whole problem may not simply be a matter in the photochemical system which is determined in terms of retinal illumination and must include higher processes of the visual system.

Summary

The assumption in this experiment is that under certain conditions (1) luminance--pupillary diameter--retinal illumination level and (2) luminance with the visual angle changed seem to be the same in the influence upon CFF. In order to investigate these two processes, the tendency of LDR changes upon CFF was used. In the first case, even when we vary luminance, the tendency of LDR was the same and the only difference was found in the level of CFF. In the second, even though we vary the visual angle with certain luminance, the difference was found only in CFF and LDR tendency never changed by these three levels of luminance. Thus, the author came to the conclusion that, if LDR variation influences CFF, and actually it does, it must be by the function of firing characteristics of fibers and the cells in the visual system, namely by the function of CNS.

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