The Association Between Retinal Sensitivity And the Glare Problem

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● ONE OF THE more frustrating problems in the consideration of the effect of glare from headlights is the difficulty involved in obtaining effective measurements during the relatively short duration of the passage of two vehicles. It has occurred to us that the discomfort and reduced visibility during headlight glare may be an adaptation problem instead of a brightness problem. This opinion has been substantiated by recent investigations of retinal sensitivity during photopic adaptation.

The luminance on the road, in the headlamp beam, is fairly high. That of the background is low. As an oncoming car approaches, from this low luminance background area, the background suddenly increases by a large factor. The rate of this increase may be more rapid than the eye as a whole (retina and pupil) can tolerate by adaptation. Consequently visual perception suffers and visibility is temporarily but dangerously reduced. The phenomenon of discomfort must be associated with the adaptation level because there is no discomfort when lighted headlamps approach during daylight.

Two vehicles moving at 50 mph, approach each other at about 160 ft per sec. If the glare is assumed to be debilitating at 1,000 ft, the glare will persist for 6 sec, until they have passed each other. Assuming that the background is nearly dark, say of luminance of less than 1 foot-candle, and that the illuminated pavement can be as bright as 15 foot-candles, what happens to retinal sensitivity during this sudden shift of background, when the approaching headlamps become annoying?

Retinal sensitivity can be assayed by the measurement of the critical fusion frequency of an alternating light stimulus (1). The extent of the variation between individuals and the association of reduced sensitivity with increasing age was described to the Highway Research Board in 1959 (2). It has been found that this reduced sensitivity is associated with a delay in shifting visual perception from low to higher levels of ambient illumination. The delay may be for a few seconds, or it may last nearly a minute. The lower retinal sensitivities are associated with greater delay to a degree that far exceeds chance, and retinal sensitivity may therefore contribute to the difficulties in night visibility under conditions of glare from the headlamps of an approaching vehicle.

In order to understand the authors' method of assessing retinal sensitivity it is first necessary to consider the phenomenological aspects of flicker, because this method is greatly different from standard or previous procedures. Usually, a large lighted area is alternated mechanically or electronically between blackness and brightness, at various ratios of light and dark. As the rate of alternation is increased, the overt perception of black and white changes to a rather random series of irregular flashes, and then, at sufficiently rapid rate, to steadiness. The change towards steadiness is not abrupt, as is often reported, but follows a normal probability function if the steps are small enough.

In this set up, the level of a large background is maintained at a steady luminance, just matching the average of the alternating stimulus. But the stimulus does not alternate between darkness and brightness, it alternates between two brightnesses, one 5 percent above and the other 5 percent below the luminance of the background, at equal intervals. The background is 50 deg in diameter, the stimulus is 1 deg, or less than the foveal area. The subject maintains foveal fixation on this spot. As the rate of alternation approaches the "critical" or threshold range, perception of the changes due to the alternating stimuli tend to fade out. At speeds above this rate, the spot itself becomes uniform, and merges into the background. During the threshold range, the spot seems to scintillate. That is, there appear to be random smaller flashes or shadows within the small alternating area. In fact, the behavior of perception seems closely analogous to the behavior of the random scintillation found in a phosphor exposed to a radiation field at low intensity. For this reason the authors prefer to describe the stimulus as alternating and the perception as scintillating, in order to avoid the semantic error of using the term "flicker" for both stimulus and perception.

Within the threshold range, the probability of a report of scintillation follows the normal probability curve of liminal measurements, varying, as alternation rate increases, from 100 percent or certainty of visual perception, to 0 percent or certainty of failure of visual perception. If the stimulus is described in milliseconds of duration of one-half cycle, instead of rate, there is a direct linear relationship between the standard deviation of the probability of seeing curve and the logarithm of the stimulus time, shorter times being associated with lower chance of perception.

In presenting the stimuli in this threshold range, it is essential that they be given in a random order. That is, the subject must not be able to anticipate his response. Although this procedure is followed assiduously in all psychological laboratories when measuring thresholds, the fact of its necessity has not extended sufficiently outside of the laboratory. Consequently the medical literature of threshold measurements for the so-called "flicker" phenomenon nearly always shows that this precaution has been neglected, resulting in many failures in this application of repetitive stimuli to the estimation of retinal sensitivity (1). In those experiments where the subject controls the stimulus rate, this error becomes maximal.

Different individuals will show different stimulus times for the 50 percent probability of seeing, or "50 percent limen." Thus a group of subjects can be graded with respect to their scintillation thresholds as an index of retinal sensitivity to a low contrast repetitive stimulus.

The experiment using this technique, which is being described in this report, included the following phases:

1. Estimate of scintillation threshold at 50 cd/m^2 (approximately 15 foot-candles).
2. A period of adaptation to dim light, at 0.3 cd/m^2 (about 0.09 foot-candles) for 5 min.
3. A reassessment of scintillation threshold at 50 cd/m^2, starting near the upper end of the liminal range.

In this procedure, it is frequently noticed that after the adaptation period the subject cannot see at all the stimulus he previously responded to with high probability. When this happens the stimulus is continued until he does respond. This delay may be too short to measure, but may require as much as ½ min for adaptation to the brightness of the background. The modal value of this delay, with the 39 subjects studied, was 5 sec. The subject was not blinded, he merely suffered a reduction of sensitivity during this period. It is believed that this is actually a glare phenomenon, and that as such, it is subject to accurate measurement.

To relate the delay period, or glare period if it may be so described, to retinal sensitivity, the data have been arranged in the double trichotomy given in Table 1. Here the actual cases are given and compared to the theoretical distribution of the same frequencies, had there been no causal relationship between sensitivity and glare. Testing this trichotomy against the null hypothesis shows $X^2 = 22.89$, with 9 deg of freedom. From this it is concluded that the data indicate 0.3 percent probability that there is no relationship between recovery from glare and retinal sensitivity.

Examination of the relative association between glare recovery and retinal sensitivity (Fig. 1) tells us that all cases of good retinal sensitivity showed fast recovery from glare, and that the majority of the cases of poor retinal sensitivity showed poor recovery from the glare.

The previous report (2) predicted that night visibility might be depressed in cases of poor retinal sensitivity, and that older persons showed such poorer sensitivity. The present report permits sharper prediction that one of the forms of decreased performance to be expected in poor retinal sensitivity will be a reduction of the capacity to overcome the effects of glare, such as occur with approaching vehicles.

Obviously more specific research is required, in which the luminances involved more nearly match those typical of night driving conditions. Such a study could serve to forewarn both elderly drivers and younger ones who have driven all day in bright

TABLE 1

DOUBLE TRICHOTOMY OF RELATIONSHIP BETWEEN SECONDS OF "GLARE" DELAY AND ARBITRARY SCORE OF RETINAL SENSITIVITY. NUMBERS IN PARENTHESES REPRESENT NULL DISTRIBUTION.

	Retinal Sensitivity			
Glare Delay	Poor 19-25	Median 26-34	Good 35-51	
Fast 0-4 sec.	3 (7.4)	7 (6.9)	8 (3.7)	18
Median 5-7 sec.	6 (5.7)	8 (5.4)	0 (2.9)	14
Slow 8-25 sec.	7 (2.9)	0 (2.7)	0 (1.4)	7
	16	15	8	39

Null hypothesis: $X^2 = 22.89$
$n' = 9$
$p = 0.003$

sunlight, of the degree of risk above average that they are exposed to when meeting headlamps at night. However, it would be naive to assume that elderly or exposed drivers would have more accidents, they will only suffer more discomfort. When it is realized that driving is a series of accident preventions, the more experienced or more careful driver will be more successful in anticipating and avoiding accidents. The value of a specific study on glare and sensitivity would lie in focussing attention on the danger, and with proper public education, could serve to reduce one of the many hazards involving night visibility.

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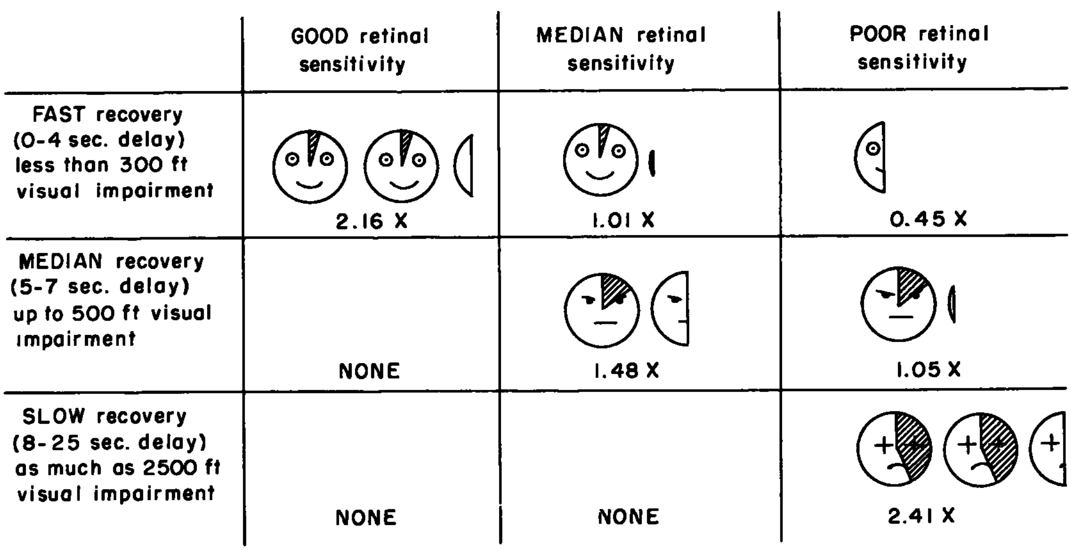

Figure 1. Relationship between actual count and pure chance prediction for glare recovery and retinal sensitivity.

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