Vision at Levels of Night Road Illumination

III. Literature 1956–57

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● BAD VISION is believed by the Association of Optical Practitioners to be a contributing factor in at least 10 percent of road accidents in Britain (4). Lighting of roads lessened accidents by a factor of ten in Indiana (7) and an accident rate in Chicago of 17.9 per million miles of travel with 0.144 ftc reduced to 9.5 with lighting of 0.88 ftc (50). Figures of merit of roadway lighting are summarized and discussed by Rex (41). Hofstetter (25) considers visual driving problems of glare, poor visibility in dim light, central acuity, peripheral vision, diplopia, judgement of direction and depth, adaptation to fixational changes of distance and the ability to recognize objects seen. Savin, Weston and Grime (44) present an excellent summary of the seeing ability of the driver and the illumination of the roads. Forbes and Katz (18) summarize many data on seeing and discuss their application to highways.

Bryan (8) and Hervey (24) report on the work that the American Optometric Association's Vision Committee is doing toward finding out the actual abilities of auto drivers. The preliminary report indicates that about 22 percent of the people tested were deficient in acuity and in depth vision, about 29 percent have inadequate muscular balance (lateral and vertical phorias), 7½ percent are deficient in color vision, 10 percent have reduced fields, and 5 percent have inadequate glare resistance. Of this group, 22 percent had reportable accidents.

The brightness of mercury lamps appears greater than the photometric brightness, with respect to sodium lamps, as the mercury luminance had to be reduced to ⅓ of that of sodium before observers judged them equally bright. Preferences for sodium light Ferguson and Stevens (16) state are due more to the characteristics of the luminaire than to less glare.

Hopkinson (26) developed a scale of apparent brightness for a 2 deg patch on a 120 deg field which shows the sensation of brightness (M) follows the physical luminance (L) according to the equation $M = kL^{0.3}$. The exponent varies with the adapting field and the surround has some effect on appearance, e.g. two luminances, one twice the other, appear at high intensity, to be about this difference, but seen in a dark surround they appear nearer to ten to one in brightness. Nolan (35) gives equations relating luminous energy, target size and duration for foveal stimuli. Stevens (47) reviews work on scales of brightness with reference to luminance.

The brightness of an object is related to and derives in part from its photometric luminance, for aside from dark adaptation, brightness is determined by the light reaching a given area of the retina and this in turn depends upon the part of the light illuminating the object which is reflected to the eye and the size of the pupil. Thus, it is evident that luminance and brightness although related are not the same, and it is the latter which triggers the driver. Someday equations will completely relate the illuminance and reflectance of the lighting engineer with the brightness of the various elements of the visual image as perceived by the retina and brain. In the meantime it behooves us to recognize the physical, biological and psychological aspects of vision, our ignorance in each field, and plan efficient experiments to obtain enough information to solve the motorist's vision problem at night. Forbes and Katz (18) also point the way here.

Aguilar and Stiles (1) conclude that at a field intensity of 100 scotopic Trolands the sensitivity of the rod mechanism to stimulus differences begins to fall off rapidly and that at about 2,000 to 5,000 Trolands the rod mechanism becomes saturated and is no longer capable of responding to an increase in stimulus.

Jayle and his associates (29-31) have investigated 1,600 young air recruits by a motion picture technic to learn at what level a screen appears lighted, the threshold for differences in luminance on the screen, for form differences and for recognition of the form seen. The latter, identification threshold (0.0058 to 0.058 ft-L) just falls in the lower range of highway luminances, and this method may provide another analytical technic. Another projection method for training night vision is described by Perdriel et al (38). The use of a tachistoscope is recommended (28) for testing driver's vision.

Actual levels of dark adaptation driving at night have been measured by Davey (10). On a dark road where the illumination varied from 0.7 to 0.2 ft-L, the adaptation level found was log $\bar{5}.79$ ft-L. In the city the level of adaptation was about log $\bar{4}.47$ ft-L and in the country it was about log $\bar{5}.17$ ft-L. From the dark adaptation curve of the subject Davey estimated that it would take about 5 min for adaptation from the city to the country lighting.

Measurements of acuity from the fovea to the periphery reported by Oliva and Aguilar (36) show visual acuity to decrease, the visual size of the retinal unit to increase and this decrease in vision is related to the distribution of the sensory units in the retina. Krauskopf (32) examined contrast thresholds during continuous seeing as the retinal image was moved by means of a mirror. Low frequency vibrations of 1, 2, and 5 cps of the retinal image were found beneficial to maintained vision, while higher frequencies of 10, 20, and 50 cps were, in the absence of normal image motion, detrimental to continuous vision. Vibration over 10 cps likewise decreased detection and resolution as shown by the graphs of Ercoles et al (15).

Finch (17) summarizes the factors involved in night visibility of roadway obstacles due to the form and shape of the obstacle and the lighting.

Sachsenweger (43) has reported that depth impressions are heightened for most people in twilight. Objects which are clearly seen to lie in different depths seem to lie in greated distances from each other in the dusk than in bright daylight. He believes that good muscle balance is important in twilight vision, because there is less stimulation outside of the macula for fusion and any night myopia present worsens the image. The various methods for estimating stereopsis are described by Anapolle (3) and he believes that all operators of moving vehicles should be tested for depth perception and stereoscopic vision.

Oliver and Lauer (37) have found that driving experience does not improve the ability to judge distance and speed. With poor visibility or poor vision the perceptual distance is shortened. Acuity and speed estimation are slightly, though not significantly, correlated; but acuity and distance perception were significantly correlated. Men were found slightly better than women in judging distance.

Davey (9) discusses visual acuity in driving based on information obtained from 40 drivers and a test course. Since vision is better out of doors than indoors it is recommended that the acuity measurements for drivers in England should be made out of doors. High acuity was not required for driving along a winding course. Visual acuity and perception time are correlated. The sharper the retinal image, the quicker it was perceived. Good acuity is helpful in seeing bus numbers, to know where they are going and in seeing via the rear view mirror. Such clues evade a person with poor vision and Davey writes: "Whether this makes him more dangerous will depend to a large extent on whether he is aware of his limitations and drives accordingly. He may, however, unwittingly balk other road users by slowing to read a road sign which is clearly visible to others and by failing to position early in the correct traffic stream in preparation for a required maneuver." Davey (11) found also that a small amount of veiling glare from slight scratches in goggles reduced the speed of speed driving, because with unscratched goggles he was able to make the same speed in the afternoon as on a gray morning, with no glare from the sun.

Mansini (34) discusses the new signs, some color coded, placed on the main highways in Rhode Island. Birren (6) reports on day and night visibility of markers. The best seeing of signs at night is about 88 percent of that during the day and he recommends white on a green background for easy visibility. Straub and Allen (48) give measurements of sign brightness with relation to position, distance and reflectorization.

Seeing involves dynamic factors not found in a camera and blurred photographs taken from a motor vehicle should not, in the writer's opinion, be used to explain vision (23) because the blur is controlled entirely by the photographer.

Danielson (13, 14) investigated the relationships of the fields of vision to safety in driving, summarizes much of the known information and adds a new measurement of his own. His results indicate that it is more important to see well in the central area than to have large areas of peripheral vision, because the peripheral vision is less useful. He was able to drive with greater comfort at high speeds when his peripheral visual fields were blocked out, but the corresponding experiment of blocking out the central fields of vision was a dangerous handicap. Danielson also discusses accidents and his recommendations deserve consideration and application.

Hopkinson (27) examined glare discomfort and pupil diameter. The pupil diameter is reported to be governed by the illumination received at the eye rather than relating directly to the discomfort sensation. More concentrated glare produced greater pupil contraction, and with intolerable glare the pupil contraction relaxes irregularly every few seconds. This instability may be an emotional reaction to the severe discomfort. At night driving luminances, the retina is not stimulated beyond its adapting ability, but the conditions producing dark adaptation are not compatible with a brief glare stimulus. The sensation of discomfort may be partly associated with opposing action of sphincter and dialator muscles due to contradictory indications from highly stimulated parts of the retina and areas of low stimulus (surround), or it may be of emotional origin. Such investigation should cast some light on the problem of successive glare in passing a number of cars.

Measurement of stray light by Boynton and his associates (12) in enucleated eyes shows a rapid falling off of the light as the glare angle increases; about 40 percent at one deg and 4 percent at two deg.

Psychiatric disorders can influence night vision. Granger (19-21) reports slightly lower thresholds for people in anxiety states, while hysterics dark adapt more slowly and their thresholds are significantly higher.

Swartout (49) has reviewed the general refractive problems of the aged and believes that for night driving increased glare sensitivity is the most serious disadvantage of age. Sheridan (45) thinks that the greatest gain in night driving vision would come if more elderly people could be convinced of the necessity of wearing their distance correction when driving.

McFarland and Fisher (33) report that dark adaptation is slower for ages 20 to 29 and 50 to 59 than for ages between these, or at greater ages. They note that "Serious questions of safety may be raised if the amount of available light is further reduced for older persons through the use of tinted windshields or colored glasses." Their measurements suggest that for each 13 years of age the light would need to be doubled to be seen just by the fully adapted eye. This is an important problem because, on the road, lighting cannot be so doubled and the older people are correspondingly handicapped. Guth (22) also has shown the need for increased illumination for equal seeing by older people. While his measurements were made at higher intensity levels than found in night driving, it is likely that the need will be at least as great for night driving vision.

According to Allen (2) the change in lens shape during accommodation is faster in youth than at maturity. Contraction of the lens is considerably slower than relaxation of the lens, but no relation was found between lens viscosity and a high accommodation-convergence accommodation ratio.

Commenting further on the glare from scratched goggles (mentioned above) Davey (11) states: "Ever since this experience I have been convinced that one of the primary reasons why a driver becomes slower with the years is that keenness of his eyesight diminishes and that, as a probable consequence of this, so does his judgment of distance."

The problems of driver licensing and re-examination have received further discussion. One set of recommendations was proposed at a symposium at New York University (5). Medical examinations are recommended and a number of medical conditions that should preclude a driving license are stated.

Porter (31) recommended that drivers be re-examined every five years to 80 and then yearly after age 80. A simple and comprehensive test chart is reported under development in New South Wales (46). The visibility measurements of Prince (40) should aid in obtaining better alphabets for charts and signs. The American Optometric Association's Driving Committee also recommends periodic re-examinations, a thorough visual examination for accident repeaters, more use of vision specialists as consultants to government, state, and other traffic boards, and that minimum standards be set up for acuity, glare resistance, adaptation to low luminance, distance judgment, width of field, and color vision (8, 24).

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