Vision at Levels of Night Road Illumination

V. Literature 1959

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For a number of years, literature on vision with information applicable to the problems of night driving seeing has been reviewed (55). This paper continues the project and endeavors to cover material on vision of interest to the Night Visibility Committee. A considerable part of the Atlanta Symposium was published (4). Current knowledge on vision is included in the new Handbook of Physiology (21), Gebhard's review (29), and the chapters on dark adaptation of (12). Colored light signals is a current CIE report (6).

MOTORIST'S VISION

Both Porter (51) and Nisemboim (46) have described requirements of motorist's vision for safe driving, including the American Optometric Association material. A series of papers by Platt (50) gives an operations analysis of the driving situation and Forbes (23) summarizes and emphasizes the psychological factors concerned in driving. Platt's contribution is too lengthy for ready review. Forbes calls attention to the time necessary for seeing and reacting to visual stimuli, that judgment may be more important than speed, and the importance of appropriate responses to hazards. The relation of optimal stimulation efficiency is discussed by Lauer (43). The use of alcohol was reported to be a significant factor in some one-vehicle accidents (34).

Proposed Canadian driving standards would require 20/30 vision for both eyes with or without glasses and 120-deg fields for drivers of heavy transport vehicles of 3 ton or more. For light vehicles of less than 3 tons, 20/30 in one eye, 20/60 or better in the other and the same field is recommended. For private vehicles, 20/40 in one eye and better than 20/200 for the other eye are the limits proposed. When one eye is not better than 20/60, the person should be limited to daylight driving. With a one-eye deficiency the use of a mirror should be required on the deficient side (58). A survey in Australia (3) discovered that 31 percent of the drivers failed one or more tests; the major deficiencies were: inadequate acuity in one eye (15 percent), both eyes (8 percent), inadequate dark adaptation (9 percent). They estimate that 0.3 to 0.6 percent of a large cross-section of people cannot be corrected to 6/12 (20/40) in the better eye. Less than 20/20 vision is uneconomical for taxi drivers (57). This may point the way toward higher standards for motorist's vision.

In Iowa, the basic information (beam candlepower of the headlights, the reflection factors of view or luminance, atmospheric conditions, glare effects, and the visual acuity of the driver) have been used to establish night driving speed limits, and these limits have been tested and supported by the Iowa Supreme Court (61). This is a good example of the integrated use of vision data.

ILLUMINATION

Night luminance levels for summer and winter terrain with varying degrees of moonlight and starlight are brought together (Cibula, 15). A series of papers by Finch (22) and his associates (14, 30) describe a measuring instrument and the importance of the brightness factor (the ratio of the foot-candles in the direction to the foot-candles normal to the surface), which may be different from the reflection factor, ρ, when specular and diffuse reflection are not directly involved. The importance of controlling contrast by properly adding light is stressed and charts are given to show how light can be added to improve contrast. Tinker (63) questions the use of threshold measurement data for the formulation of specifications for illumination. Dreyer (18) presents information on just perceptible and just imperceptible stimuli. His results seem to depend on a decrease in sensitivity of the area stimulated being greater than the slower rise in sensitivity that follows a corresponding stimulus, of luminance less than that of the background.

GLARE

The report of Fry's committee of the Illuminating Engineering Society gives formulas for the specification of glare, a nomogram, and discussion of the calculation of glare with respect to comfort and discomfort (27).

Guth and McNelis (33) describe their glare evaluater and Hopkinson and Bradley (37) have formulated a scale for the magnitude of the glare sensation. Glare discomfort is stated to be equal to a constant times the source brightness raised to the 1.23 power. Luminance changes in retinal acuity, by Johnsen et al., show significant effects of glare on adaptation (40). Unfortunately, the levels used in the experiment did not extend into the night driving range; such work could be useful.

Highway lighting is a subject of lively disagreement, judging from the discussion following Fowle and Kaercher's (26) endeavor to set theoretical bases and Waldbauer's (64, 65) discussion on glare-free lighting. Some of the difficulties depend on seeing distance defined as the perception of an object of given size and contrast, or to include "...be detected in order to take proper action to deal with it" (26). Either method should be useful provided it is made clear which is being considered. When one uses reaction-seeing distances, these then have to be large enough to permit the required action at that time for the actual condition of the roadway. It would seem preferable to use perception seeing distances and weight these as required when driver response is also involved. Rex (54) proposes a method for the analysis of roadway lighting in terms of relative visibility and disability from veiling brightnesses.

VISION

Too little attention is being given to problems of the total time involved between the appearance of some object and the necessary action for safe driving. Some of these responses take time, and a high-speed vehicle may cover considerable distance during the interval. The problems of evasive action are far less with automobile driving than flying of superspeed airplanes, though some of the data from the latter are of use in highway problems. Stereo threshold times indicate that aviators can start an evasive action in about 2.5 sec (Diamond, 17). Similar conditions may be involved when passing vehicles on the highway. The stereoscopic threshold increases with increased illumination and shows a break at the rod-cone transition and unequal illumination of the eyes causes variation in depth perception (44).

When steadily viewing an object, the accommodative focusing mechanism of the eye shows short fluctuations from 0 to 0.5 cycles per second, and with large pupils other fluctuations near 2 cycles per second. When the eye is viewing an empty field, the higher frequency components diminish and lower frequency components increase (Campbell, 13).

Ocular movements of 15 to 90 deg were studied by Hyde (38). Short saccade movements tend to overshoot and long saccades tend to undershoot the target. With 30-deg movements, inward movements of the eyes to the primary position are faster than outward movements. With long eye movements, the rate speeds up and then slows down. There are more corrective movements at the primary point (straight ahead view) than from more peripheral targets. The information on time factors is useful. Small eye movements cover from the center of the highway to a sign on the shoulder. Longer movements are required when looking down approaching roads. Moving the eyes continuously over large areas is desirable, but also takes time.

Goodson and Miller (31) report that dynamic visual acuity begins to deteriorate with eye movements of 20 deg per second, though not appreciably until eye movements of 30 deg per second are reached. Measurements made in the air proved similar to those made in the laboratory. The rate of decrease in acuity was linear for two targets, but curvilinear for one target. Deceleration has a marked effect on the performance, both from the change in speed and the change in configuration of targets. The placement of signs along the highway should be such that the eye does not have to move more rapidly than 20 deg per second for the time needed to perceive what the sign says.

The decrease of acuity as the image falls away from the very center of the fovea, is shown again to fall off rapidly in the first 5 deg. Held (36) has combined a study of acuity from center to periphery together with the effect of blurring the acuity with positive lenses. There is a slight improvement from the blur from a +0. 50 diopter lens. A slightly out of focus image can aid resolution.

The easier seeing of small objects aligned at 90 and 180 deg to the horizontal is explained by Weymouth (66) in that rays from the images add in these directions, but not at oblique directions (45 and 135 deg). Amblyopic and some defective eyes seem to work better with lower intensities than with high intensities and this may be a fortunate compensation which should be kept in mind in establishing the ability of such an individual to drive (47). A similar finding, and also that the proper spacing of letters markedly improves vision, is reported by Prince (52). Contrast is important in visual search (42). The incorporation of some of this information in the design of signs might improve legibility. Eastman's new chart for testing astigmatism is proving useful (9).

The response of the pupil of the eye to changed illumination is stimulated by both rods and cones, although the cones were a more efficient stimulus (1). The pupil response is greater with photopic than with scotopic vision (45). Studies on dark adaptation by Baker et al. (7) and Sweeney (62) indicate a rise in the threshold before adaptation progresses, and that up to two log units the energy in the test flash does not affect dark adaptation significantly. Neural factors may be concerned in monocular dark adaptation (8).

In experiments with flickering light, and also in some conditions of photometric measurement, Kelley (41) has found that the edge enhancement behavior, where the observer response is mainly to the edge gradient while the experimentor is controlling only a large area of luminance, is important. Peckham (48, 49) finds a time summation in critical flicker fusion. Analysis of averages and normal curve fits shows that there is a 25:1 decrease in retinal sensitivity with old (51-80) as compared with younger (32-50) eyes. This is another measure of senility that needs further analysis. Projector (53) gives formulas for comparing the efficiency of flashing and steady lights and Ives (39) discusses visual signals of short duration. Alternating flicker duration studies are reported (24).

A case of night myopia is presented by Fulthorpe wherein the night myopia was mainly due to the spherical abberation accompanying large pupils (28). Space myopia is an active topic (20) altho probably not a factor in motoring.

Visibility from automobiles is more restricted as manufacturers reduce the height of the cars. Both Sutro (60) and Fosberry (25) discuss problems of design with respect to vision. This information should be helpful to the designer of automobiles. Motorists dependent on glasses for vision, especially truck drivers, are urged to carry a spare so that they can still see in case of damage to their spectacles (5).

COLOR

The Council of Industrial Health, American Medical Association, has again opposed tinted glasses and windshields for night driving (2). "The use of any 'night-driving' lens or windshields, whether tinted, reflecting, or polarizing, reduces the light transmitted to the eye, and renders the task of seeing at night more difficult. The source of glare in night driving is the contrast between the headlights of oncoming cars and the darker surroundings. The use of tinted lenses or windshields does not reduce the contrast but reduces the intensity of illumination from both the headlights and the surroundings, thereby impairing vision. There is no scientific evidence to support any claim that the use of tinted lenses or windshields improves night vision." Yellow glasses reduce recovery time after glare by about 12 percent and the seeing time in the presence of glare about 29 percent according to Davey (16).

Recent proposals for tinting highways with various colors and for use of fluorescent color markings for night driving suggest careful study as to the effect these will have in seeing after dark. Heath and Schmidt (35) have examined color recognition by those with defective color vision. The recognition of colors is improved when both white and red are seen in the same field of view. They report that bluish-green tends to be called green, and yellowish-green tends to be called red. In general, the limits for signals proposed by Judd were approved. Breckenridge (10) has given a check list of the conditions affecting the probability that a signal light will be recognized, and discusses color signal standards. An international report on colors of light signals is available (6).

From a study of low contrast, Ronchi (56) proposes that for perception of low contrast, it is essential that one should eliminate with suitable filters either the blue or the green, as the presence of both blue and green impairs the perception of contrast at low luminances. This may be another factor contributing to the difficulty of seeing at dusk. Noise, according to Grognot and Perdriel (32), of 100 decibels decreases the size of visual fields and color perception, although not producing visual acuity.

With regard to Land's recent contributions to color vision, Wolfson (67) indicates that Land's observations are explainable by color constancy and gives computations to show compatability with the Young-Helmholtz theroy. Brown (11) calls attention to the Fechner colors obtained from black and white pictures.

RESEARCH

A considerable amount of money is granted to the Division of Optometry of Indiana University to (1) determine the visual demands of night driving, (2) for determination, measurement and appraisal of normal and abnormal skills and responses which relate to these demands, (3) for the derivation of reliable tests and instruments, and (4) for the publication of the results (19).

At the Chicago 3rd Annual Conference on Motorist's Vision (unpublished) the following topics were proposed for research: task analysis and time motion study, correlation with the total time the attribute of driving is used in actual driving, dynamic side visual acuity, the intercorrelation of tests of acuity (Snellen-Orthorater, etc.), an efficient test for acuity against glare, and coordination of the research people with those who must apply the results on the highway. Most of these suggestions were made by B.H. Fox.

A preliminary report of the California Research Project (59) suggests that drivers with good vision outdrive their seeing, those with normal lateral vision have fewer signal violations, drivers with better side vision are more involved with speeding and less for not stopping at thruways, those with better vision on the right side have fewer accidents and other interesting correlations. The completion of the project should provide much interesting material on motorist's vision.

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