Vision at Levels of Night Road Illumination

X. Literature 1964

OSCAR W. RICHARDS
Chief Biologist, American Optical Co., Southbridge, Massachusetts

•SOME contributions to the literature on vision applicable to night driving (76) include reviews by Duntly (36), Onley (71) and the Swedish symposium (49). Mrs. Wiener (97) gives a bibliography of the past decade, and form discrimination was examined at the Brown University symposium (7). Boynton (21) discusses receptor excitation and Bryngahl (22-23) uses sine wave stimulation and transfer functions for the analysis of mesopic vision. Tabulae Biologica adds another section on the eye (38).

Rules for night driving by a French physician resemble those in use elsewhere (95). The German symposium (42) and Sartori (82) consider the medical problems of evaluating adequate vision for driving and the first year of compulsory vision examination of drivers in Bavaria. The guidebook (5) of the American Medical Association gives visual and other criteria for driver evaluation. These problems become more important with periodic retesting of drivers and the need to decide whether the person almost passing the screening test can compensate for the vision deficiency, or should lose his license to drive.

The opposite problem of how to select the superior driver has led Uhlaner and Drucker (91) to conclude that psychophysical measures (such as vision tests) provide only minor help and that other attributes are of greater importance to safe driving. In England, Roslyn (81) proposed that the vehicle as well as the driver should have a certificate of fitness, but the Authority replied that such would only tell the condition at the time of examination, not at a later time, and also that standards would be needed. Connolly (26) reviews the nature of seeing from autos and comments on other vision problems (28). Kent's review (59) of the visual ability required for job performance on a submarine suggests a comparable study of automobile driving would be useful.

Accidents (101), driver error measurements (73), simulation methods (75), and following behavior (90) are reported, and the use of eye-movement cameras is again suggested for the analysis of driving seeing problems (64). Davey (32, 33) comments on the British Auto Show, mainly about night lighting and poor placing of headlights. American car lights are criticized as not being visible from the sides. Connolly reviews the problems of seeing rearward and the evolution of rear-view mirrors, and Davey (34) reports the conference on rear-view seeing at the Northampton College of Advanced Technology.

A standard daylight that avoids the variation in the ratio of sun and skylight, in sun angle (25), and atmospheric attenuation would be useful reference, and Judd (55) summarizes numerical data and reports progress towards such a standard. Moonlight luminances for elevation and phase of the moon are recorded by Nichols and Powers (69), also some night vision research with moonlight.

The American Standard Practice for Roadway Lighting is revised (8). An interesting summary of British research on road lighting (35) shows a 30 percent accident rate reduction at 64 sites lighted to group A (enough light that auto headlights need not be used). Amber direction beams of 100-500 cd are recommended. The American report (13) also proposes yellow signals.

Polarized light and its possible introduction was considered at the Swedish symposium on road lighting (49). The chapters by Schober and Wright give useful informa-

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tion on night driving seeing and should be ready by workers in this field. The vertical distribution of light was considered to be of more importance than mere horizontal footcandle distributions. Wright emphasized the importance of gradient junctures in contrast which reveal or conceal an object, and that brightness (both footlamberts and the psychological perception) is more important for planning road illumination to give good seeing than are horizontal footcandles. Birkhoff (18) is investigating similar problems. Blackwell (19, 20) discusses lighting geometry and compares fluorescent, mercury and tungsten lighting for roadways.

Automobiles, Allen and Clark (4) believe, should have running lights of at least 4-in. diameter and $1 - 3 \times 10^4$ fL to help compensate for the variation in visibility of the autos against various surrounds and the difficulties of seeing at twilight (3). Rooney (79) states that plastic reflective markers are useful in bad weather because they do not disappear when wet. Button and large area reflectorized stop signs compared by Hulbert (48) show little difference in effectiveness.

The autokinetic movement of an intermittent illuminant usually increases with less illumination, but the relation is curved upward for the 5 to 15 cps range despite the expected brightness enhancement (85). The discrepancy is attributed to redundancy in the visual field.

Grant (43) discusses definitions of glare largely in terms of the 1920-30's. Fatigue increases with continued exposure to glare in Hartmann's (45) simulation study. Glare recovery time averages from 2.9 sec at 0.2 fc for 1.5-sec exposure to 8.8 sec at 0.74 fc for 30-sec exposure. Changes in adaptation are of small consequence for ordinary car meeting as they only slightly affect the redetection time for a roadside object (54). Instant flash-blindness is being investigated (47).

Vision is essential to but is not a sufficient condition for safe driving. Many other factors are involved within and without the driver. Yet pleas to correlate accidents and vision continue (10). Jackson (50) states that there is no correlation between visual function and road accidents. Vision from the driver's seat is improving according to Fosberry and Moore (40), more so forward than to the rear.

Vision standards for French drivers vary from 0.6 (about 20/33) for light vehicles to 0.7 and 0.9, or 0.6 and 1.0 (about 20/30 and 20/22, or 20/33 and 20/20) for drivers of heavy vehicles.

The question of how well people see has two new answers. A large survey of binocular vision (92) found 76 percent of people (uncorrected) reaching 20/40 or better and when corrected 95 percent were 20/40 or better. A median acuity (with correction) of 20/30 was found to about age 75 and (uncorrected) 20/40 to age 58 for females and to 70 for males. An analysis of 1,000 refractions (16) showed one eye 20/30 or better to about age 70 and 20/20 to about age 50. Such information is essential to a decision as to what age and how often vision of drivers should be retested for safety and at an economical cost.

Foveal vision of targets (50-1,600 fc) was not greatly decreased by filters absorbing 99 percent when contrast was high, but with poor lighting vision was degraded (72). Luminance fluctuations of small magnitude did not greatly affect thresholds at screen luminances of 0.01 to 0.1 fL, but do so at 1 fL (67).

Burg (24) reports correlation between good dynamic visual acuity and driving citations (i.e., a good driving record), but not with static visual acuity or accidents. Form changes in a pattern can make it appear at various distances and Johansson (51) is using this interesting approach to examine depth perception. Accommodation and fatigue are problems when observing a target moving toward the eye at 0-200 cm/sec (87). Whiteside (99) reviews the illusions of movement perception. Threshold size is reported to be a linear function of the speed of motion; the constants of the equation have small variation between observers (17). An abstract (41) reports progress in mathematical description of the position, velocity, and acceleration for perspective transformation of the moving ground plane.

Wearing of tinted glasses (9-20 percent transmittance) reduced stereoscopic visual acuity an average of 21-29 percent for 57 percent of 34 subjects. No change was found for 29 percent, and 13 percent showed an increase in stereopsis (80). Lall and Kitching (62) report the average stereo acuity of emmetropes without phorias as 2.55 sec arc.

The acuity is poor at mesopic luminance and improves with increasing light. Stereoscopic acuity also increases with better correction of the errors of refraction of the eyes--another reason for the best possible correction of vision when driving is to be done at night. The visuo-motor reaction time is reported to be slightly less for binocular than for monocular vision (30).

Forbes et al. (39) provide an extensive bibliography on the detectability and legibility of signs, and incidently on other aspects of vision. Johansson and associates (52) found speed limit signs to be seen 78 percent of the time, but unspecified warning signs and pedestrian crossing signs were seen only 18 and 17 percent of the time. Signs are seen in terms of their significance to person or property, and unnecessary signs distract the driver's attention to no significant purpose.

A hand-held driver vision screening device is described (93) and Young (100) gives details on how small photocells mounted on a spectacle frame are used to detect eye movements and send the information to the computer center. The continuously variable multifocal "Verilux" lens is reported good for driving except that they were dangerous when backing (74). Variation in the extent of nasal visual fields is reported by Cutler and Davey (31). Heimstra (46) finds mental fatigue more serious than skill fatigue as far as vigilance and target detection are parts of driving performance. It is difficult to conclude whether the decrements are due to changes in motivation or physiological changes due to fatigue. The effects of previous concentrated mental operations are not immediately apparent, but are progressively more noticeable as a function of time.

Luria and Dimmick (63) discuss color vision, Walraven (98) has written a monograph, and Wald (96) considers recent information on the retinal receptors and gives information on the transmittances of the internal eye media. Color vision at mesopic levels (0.1-0.01 fL) was measured by Kinney (60) and this information should be utilized in any attempt to color code signs for use in night driving. Connors (29) reported that surround brightness does not affect hue discrimination until the surround is three times brighter than the stimulus.

The U. S. Standard Colors for Signal Lights is available (94) and an instrument is described for measurement of the color of light from signal devices (83). The extension of the red limit of the U. S. Standard is believed undesirable because it is a handicap for people with deficient color vision (68). New measurements are published for the kinds of errors made by deficients and their significance is discussed. Nathan et al. (68) state further that no yellow filter tested was satisfactory for people with defective color vision. Richards (78) reviews the literature on yellow glasses, giving further evidence that yellow glasses should not be worn at night. Both Kleyhaur (61) and Richards (77) warn against wearing the darker shades of contact lenses when driving at night. The American Medical Association's warning against tinted glasses and windshields for night driving is republished (5).

The lighting study project (13) recommends amber signal lights, and Fosberry and Moore (40) list their advantages. Allen (1, 3, 4) advises against the use of yellow, because he doubts that the lower brightness of the yellow can be overcome and that replacing regular bulbs with yellow painted bulbs dangerously reduces the brightness (14). Blackwell has previously commented on the near impossibility of localizing a single flashing amber light. While two signal lights are better than one, usually only one light is used at a time as a direction signal. I find no satisfactory evidence that seeing is better with yellow light. It is a handicap for people with deficient color vision when red and green lights are also in the fields of view. Medium grade deficients will be hard put to tell whether a light is red, green or yellow and which way it is moving under poor conditions of visibility (in fog, rain, etc.).

Allen (102) recommends changing the rear red light on automobiles to green, because he believes that some two-thirds of the population see red behind green and think that red is farther away than it actually is.

Vibration effects on humans are reviewed by Nadel (66) and Teare and Parks (89) report severe deterioration of vision from 12-24 cps vibration, a possible linkage with the critical flicker frequency of the eye.

Drug effects on the driver's vision may well be dangerous (88), and general articles on drug effects appeared last year (65, 70, 84). Bilberry pigment extract is reported to improve night vision (9); considering the widespread occurrence of anthocyanin, (e.g., in beets) this finding needs confirmation. Smoking two cigarettes within 15 minutes did not affect night driving ability (53). Feeding alcohol to 6 subjects did not affect visual acuity or color vision other than that their responses were slower. Eye phorias and ductions were affected adversely in half of the subjects and the peripheral visual fields of all were reduced (86). The diurnal variation of intraocular pressure in glacoma (57) and other cyclic changes may affect night vision.

Medical problems and the responsibility of ophthalmologists are under consideration (42). When the patient has been warned by the practitioner that his vision is inadequate for driving, it is held that the practitioner has done his duty and is not responsible if the patient disregards the advice (37, 44). Allen (2) calls attention to the extent of eye injuries in automobile accidents. Degeneration of the retina and opacities of the lens may disqualify the elderly from driving (15). Thermal tolerances of the skin are available (58). Accident-prone drivers may be those who do not mature (56).

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