# VISION, VEHICLES AND HIGHWAY SAFETY

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Assuming a sound, reliable, controllable motor vehicle and freedom from catastrophic interferences as might occur from mechanical failure of another vehicle, a motorist depends almost exclusively on vision-derived information to keep him safe from an accident. Although vision isn't everything needed for safe driving, it is an absolute minimum requirement.

The visual problems involve the driver and his visual readiness to drive; the vehicle and its "designed-in" features or limitations; the vehicle and its environment; and the signal systems for traffic, for vehicle location and driver communication.

Emergency vehicles, school buses, trucks and trains, automobiles, motorcycles, pedestrians and children all have one thing in common, they are often invisible, and the price paid for colliding with them is human lives. This article reviews the visual aspects of highway safety and offers a considerable number of recommendations.

## Drivers Vision and Driver Licensing

Visual Acuity. —A man with 20/20 vision driving at 60 mph has 3.9 seconds to read a highway sign composed of 6-in. letters. If his acuity is 20/40 he has only 1.95 seconds and with 20/100 acuity he must try to read the sign in 0.77 seconds! The man with 20/40 by day will have less than 20/100 at night, and he needs considerably more light than he would to see roadside or highway hazards.

A person can have poor vision, 20/40 or less, because typically he needs a spectacle correction for myopia or astigmatism, or often because he has a beginning clouding of the lens (cataract), or occasionally because of pathology in the retina of the eye or in the brain. Each of these conditions causing lowered visual acuity, as measured in the daytime, causes an increased handicap at night.

As much as 100 times more light might be required to see a visual hazard at night when the driver has only 20/40 daytime acuity as would be required if he had 20/20 daytime acuity. In other words, 20/40 by day merely cuts the critical perception distance in half compared to 20/20, while at night it may cut it to 1/10th or less.

With highway speeds increasing it is unreasonable to expect a driver to operate a vehicle safely by day with 20/40 or less acuity. By night, no person with only 20/40 day acuity should ever be permitted to drive. The driver with 20/40 or worse acuity—if allowed to drive at all—should be restricted to non-highway driving and only in the daytime. The outcry of hardship on drivers

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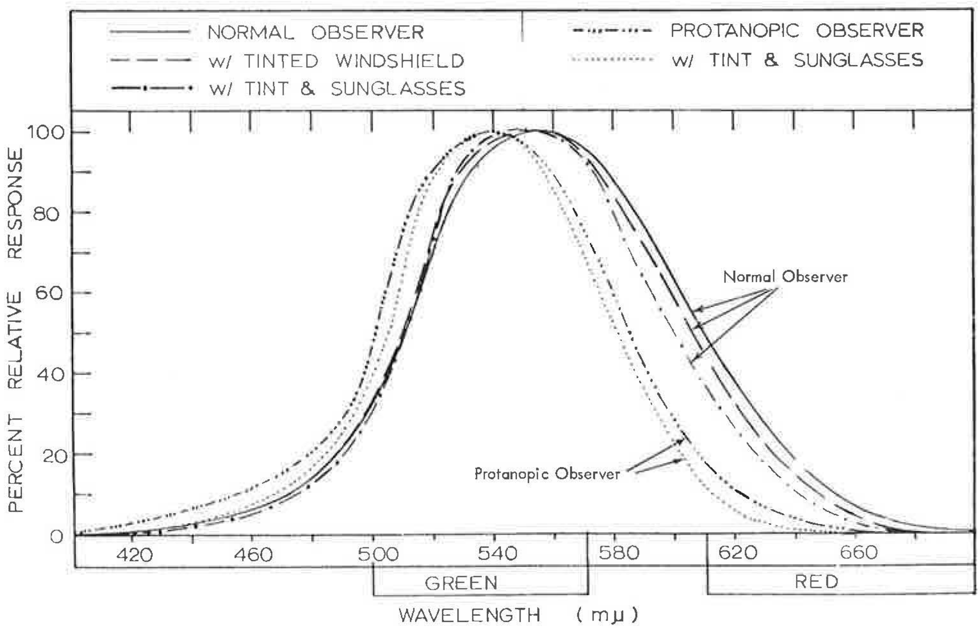
who can't achieve better than 20/40 is to be balanced against data that show that virtually all persons below the age of 70 are capable of correction to 20/20 vision.

Peripheral Vision. —The increase in the number of vehicles, of the complexity of the highway system and of overall speed, make it impossible to monitor traffic solely with careful use of central vision. The more complex the scene, the more one must rely on the maximum capabilities of his visual system including peripheral vision. A restriction in one's visual fields or an impairment of peripheral vision cannot be compensated in an automobile merely by adding mirrors.

If there is any restriction of the limits of the field of vision, it is abnormal and may be an ominous sign of eye or brain pathology. Such persons should not be permitted to drive without permission from a vision expert. One should be able to see things happening 90° or more away from the line of sight, i.e., directly to the side when looking straight ahead. If this angle is reduced to less than 70°, whatever the reason, including wide rim spectacles, the driver should be denied a license. If any exception is made, he must be severely restricted to daytime driving on other than main highways, i.e., to driving that is least likely to cause an accident. Seventy degrees to the side means a total visual field of 140°.

Color Vision. —Studies have shown that color defective people require twice as long to recognize and act on signal lights as do normal individuals. The number of errors in recognizing the color increases for color defectives, and for color-blind individuals color cannot be used to convey information. Drivers should know they are color blind or color defective and know what the hazards are. Protanopic and protanomalous color defectives make up about 2 percent of the male population and are characterized by an extremely low sensitivity to red light. A color defective individual may not even detect a red light as having been turned on, much less recognize its color (see figure).



Such persons should not drive in fog or at night where often the only clue to danger is a red taillight.

They should be restricted to slower driving at all times. The only solution to their problem is to change our vehicle light system to green taillights and to bright orange-red brakelights, and to brighten traffic signals using more orange and yellow in the red signal, and blue in the green signal.

People who have trouble on a color vision test should be referred for professional evaluation of the type of color vision defect and the advisability of restricting licensure. Up to 7 percent of men have some color vision anomaly, but most would not need to be restricted. A warning of the increased hazard, the possibility for confusion, wrong judgments, and the need for a longer perception time, should be forcefully given.

Color vision abnormality, low acuity and visual field defects would be additive in their detrimental effects on overall visual performance of the driver, and a combination of two or more should be cause for restricting driving privileges even though each alone is not severe enough to cause an individual to fail to meet the set standards.

Night Vision. —Testing for dark adaptation ability is difficult, time consuming and expensive. Furthermore, it is unnecessary, because a test of visual performance on a low contrast target and at a lowered luminance gives the needed information. The night vision performance tester developed at Indiana University's Division of Optometry measures disability at night in terms of how much light is needed to perform a specific task. Failure on this test should restrict the driver to daytime driving or encourage his having an eye examination to see if the night performance can be improved. Almost all of those under 60 years of age can be corrected to pass such a test. The number who would fail this night seeing test among our present day drivers is estimated at about 20 percent.

The older drivers will have a higher percentage of failures, but virtually all drivers would pass with proper lenses. In this test, failure is determined by the need for 5 times more light to perform the visual task than would be necessary for a normal person of 20 to 35 years of age having no refractive error or wearing a correction for whatever refractive error he may have.

Glare resistance goes down as light requirement goes up and hence the measure of glare resistance as such is not necessary. Dynamic visual acuity falls off as retinal image contrast falls off; hence poor night performance would probably correlate with poor dynamic visual acuity.

It is believed also that dynamic acuity will correlate positively with good ocular muscle coordination. Dynamic acuity would then be predictable on the basis of the performance on the Night Vision Performance Tester and the muscle balance test such as given in the Orthorater or Sight Screener type of instrument.

Muscle Balance. —A farsighted person typically has 20/20 vision and routinely passes all acuity tests. This does not necessarily mean that a farsighted person is a safe driver. To overcome farsightedness and obtain 20/20 acuity, the person so afflicted needs to accommodate or focus his eyes. The greater the farsightedness, the greater the accommodative effort. Unfortunately accommodation causes the eyes to tend to converge and this tendency makes the farsighted person dangerous for night driving. Fatigue, alcohol, darkness and carbon monoxide also produce the same tendency to converge. Furthermore they reduce the ability to compensate for the tendency to converge. A fatigued, farsighted driver, at night may suddenly become confused and crash, because of his eyes crossing without warning.

Any deviation of the posture of the eyes from normal which is detected during a driver's license eye test should be basis for a referral or the issuing of a license restricted to daytime driving only. Since 70 percent of our population is farsighted and will usually manifest good acuity, and since most accidents happen to people with good acuity as determined by often quoted statistics, it is apparent that licensing examinations must be concerned about other things besides visual acuity.

In this regard, it is wrong for a licensing agent to issue an unrestricted driver's license permitting the applicant to drive without glasses, when he notes that the applicant is wearing glasses and can demonstrate 20/20 vision without them.

## Vehicle Visibility Problems

Automobile. —Automobiles can and do become invisible in the daytime as well as at night. Two effects occur. One, like an egg in the snow, is due to a lack of contrast with the background; the other is like a tiger in the thicket where the complex background blends with the tiger's stripes. A moving vehicle on a collision course with a given car does not appear to move across the driver's field of view, but merely to grow in size until impact occurs.

Peripheral vision is most acute for moving objects, hence a collision course is easily the least stimulus to peripheral vision. If there is nothing of attention-getting value on the approaching car, it can be overlooked until too late. Since white cars are poor in snow and dark cars are poor at almost all other times, it is necessary to add lights for increased conspicuousness both by day and at night. Running lights both front and rear have been shown to reduce accidents, and many commerical truck lines and bus companies now operate with headlights on at all times.

In addition to low visibility of the car, truck or bus, the ability to see out of these vehicles is quite impaired. For most automobiles a loss in eye height occurs which is a considerable handicap both in seeing objects and in judging distances. A survey made early this year showed that over 90 percent of dealer stocks of new cars had tinted windshields. That this is a serious problem may be seen by parking at night and looking through the windshield and around the windshield several times. The greater the age of the observer in this experiment, the more startling will be the differences noted.

Red light transmission drops 60 percent, while white light transmission drops 30 percent, fully the equivalent of losing 1 headlight in the 4 headlight array on most cars. Furthermore, scratches, dirt, poor quality glass, and internal reflections measurably degrade the image seen through the windshield. In the daytime, chromium glare, hood glare, and glare from windshield backlighting from the top of the dash panel, all detract from vision, in some cases producing temporary blindness in a very real sense. (Much improvement has been made in American automobiles in 1967 and more is promised by GSA standards in 1968; little change in truck or bus practices has been noted.) Obstructions to vision from mirrors, distorted windows, corner posts, and wide metal panels beside the head of the rear seat passenger have caused many "I didn't see" accidents.

The distractions of radio, ash tray, control knobs, and the instrument cluster itself are capable of teaming up with any or all factors discussed above or of acting alone to cause accidents.

The motor vehicle must be improved to help meet the increasing demands placed on vision, by reducing visual interference to an absolute minimum, and eliminating visual distractions by standardized instrument and knob placement, shape and function, etc.

School Buses. —School buses represent an especially important problem. They must be easily seen and accurately localized. At night, points of light are not good for localization as is proved in the laboratory and by rising numbers of rear-end collisions into "fully lighted" trucks or cars. Single or multiple taillights, clearance lights, or running lights do not locate a vehicle precisely until fill-in light is provided, or structure and size are supplied.

Lights that illuminate the bus itself and the ground around it supply the needed visual information. The use of a reflectorized stripe 5 or 10 in. wide outlining the rear, front and sides of the bus would serve the same purpose almost as well as total surface reflectorization. The stripe should be as low as possible on all four sides to help localize the vehicle with respect to the roadway.

In the daytime increased visibility by use of fluorescent yellow or orange yellow (not red) is indicated. Red paint, or simultaneously flashing red lights, or alternately flashing red, or yellow lights alone, should never be used as they are either not visible, are poorly visible, do not mean stop and/or are falsely localized in space when other visual clues are absent.

The school bus signal arm should be lowered to driver eye level or below. It should be reflectorized, painted with fluorescent paint and include the word "STOP" as well as carry a bright red light of 1200 to 1500 candle power shining both to the front and to the rear.

Emergency Vehicles. —Emergency vehicles suffer the same problems as other vehicles, plus the handicap that legislators believe that red is a conspicuous color while in fact it is less than one-fourth as conspicuous as white when actual roadway measurements are made. Fluorescent yellow or orange paint should be used for daytime protection and extensive use of reflectorized tape in yellow, orange or white should be applied for nighttime visibility. Lights mounted to light the sides of the vehicle and the roadway around the vehicle will increase its conspicuity and reveal its nature quite effectively.

The heavy reliance on red light as a protective or warning color is not wise in view of its unfavorable position among other colors so far as visual efficiency, peripheral vision, twilight vision, and color vision defects are concerned. Brightness, no matter what the color, makes an object or a light come to one's attention. Since it is hardly ever possible, in a dynamic highway scene, to be looking directly at a signal when it comes on, one must, for virtually every signal received, first receive it on his peripheral retina.

For this signal to reach attention it must rise above a threshold value. In the extreme periphery, high signal strength (brightness) is required; whereas in the fovea, a mere color change might be enough. Most studies on signal color efficiency use central vision only and are subject to serious question where dynamic seeing is involved. Attracting attention of course is the goal, and depends on brightness. Identification may depend on color recognition.

## Running Lights, Taillights and Signal Lights

Because of the many visual problems detailed above, every vehicle should be as conspicuous as possible. This means lights both front and rear by day and night. These running lights should each be visible throughout 225° so there are at least two or more lights visible from any point of view of the vehicle. The forward-facing lights should be white, at the level of the headlights, and at least equivalent in visibility to a fully energized 21 cp bare filament clear envelope bulb. The rear-facing lights should be a blue-green, and at least equal in visibility to that provided by a fully energized 32 cp, bare filament lamp seen through a transparent blue-green filter of about 40 percent transmission. Stray upward light onto snow or rain droplets in the field of view of the driver should be controlled.

The rear-facing green running lights should be about 24 in. above the pavement on all vehicles—trucks, buses, house trailers, etc. The white and green running lights should always burn steadily so long as the vehicle's engine is running. These lights locate the position of the vehicle best when placed low and are kept at standard brightness, size and separation. Localization is better at night if fill-in light falling on the car (truck or bus) and on the highway is also provided, and if reflectorization is used to outline the vehicle.

Orange-red brakelights should be above the green running lights and separated from them between 3 and 6 in. They should be of 1200 cp and visible throughout 225°. A pair of 1200-cp orange-red brakelights should also be displayed on the roof of the automobile (or on the back of larger vehicles) at a standardized height, e. g., 5 ft above the roadway, and visible at full brightness throughout 180° when braking. This has been shown to reduce the reaction time and hence the probability of chain rear-end collisions on crowded multilane highways.

Turn-signal lights should be located above the brakelights on the rear of the automobile and may be yellow or red of 1200 to 1500 cp and visible throughout 225° at full brightness. Front turn-signal lights should be 3 to 6 in. above the headlights, each visible throughout 225° at full brightness of 1200 to 1500 cp. They should be white to differentiate them from rear turn signals. The flash rate of turn signals must increase from the 1 to 2 per second currently in vogue (for non-visual reasons) to 5 to 9 flashes per second, with an on-off ratio between 1/1 and 1/2. This will raise their conspicuity by at least a factor of 2 and perhaps more than 10 when the probability of seeing the longer flashes is considered. The higher flash rate also would eliminate the confusion now caused by the driver who pumps his brake while his turn signal is operating.

Shape coding of the rear of a vehicle by placing a single green running light on the centerline, 5 ft above the road, midway between the high-mounted brakelights will prevent a color-blind motorist from thinking an approaching car is going away.

Shape coding the front as a rectangle by adding two white 21-cp running lights at the 5-ft level and at the same width as the lower running lights would permit two additional benefits. The high-mounted running lights would give advance warning of an approaching vehicle on hilly roads, and would provide light for overhead reflectorized signs. This upward light is spilled off the head lamps at present and cuts across the line of sight to illuminate snow, fog, and rain with losses in seeing ability. There should be no upward spill from low-placed lights nor downward spill from high-placed lights, hence avoiding the driver's visual zone.

The above specified signal intensities are patterned after the method used by the SAE in setting signal specifications. The SAE method is poorly representative of the actual visibility of a light because it does not specify the intensity per unit area of the signal source. Some advantages can be obtained by using a small very high intensity source such as a vare filament. Other characteristics of merit are provided by larger areas of lower intensity. What the desired characteristics of brake and turn signals should be has not been studied enough to be more exactly specified at this time.

Front turn signals are currently placed low to improve the background and hence the conspicuity. Research has shown that when the intensity of the signal is adequate, the background under normal ambient conditions has no effect. The low position has significant limitations in dense freeway traffic particularly for late change signaling and should give way to the superior all around visibility location near or on the top of the fender.