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Vision Screening for Driver Licensure

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In the past 40 years the percentage of drivers who are 60 or older has increased from 5 to 15 percent *(1)*. Improvements in medical technology and health care delivery along with the aging of the post-World War II Baby Boom population will certainly cause this percentage to increase in the coming years. Those over 75 make up our nation's fastest-growing age group; their numbers are expected to double by the end of this century.

The elderly driver has more traffic safety difficulties than the younger driver. Staplin et al. *(2)* report that those 65 and older represent 12 percent of the population and have 13 percent of the accidents. At first glance this does not seem to be a disproportionate accident rate. However, as a group the elderly drive fewer miles, and many do not drive at all. When expressed in terms of accidents per miles driven, the accident rate of the elderly is the highest of any age group except teenagers. Burg *(3, 4)* showed that there is a slight increase in accident rate beginning at age 55, but when the increase at age 55 is expressed in terms of accidents per miles driven, it becomes striking. Koltnow *(5)* found that although U.S. traffic fatalities dropped 14 percent between 1980 and 1982, there was no decrease for drivers over 65 and women over 65 experienced a 14 percent increase. Koltnow also points out that the elderly are more physically vulnerable and are more likely to be killed or injured in a crash that would not cause such serious injury to a younger individual.

Although there are many aspects of human performance that are related to driving ability, vision is the primary sensory input on which the driver

depends. It is commonly estimated that 90 percent of the input that a driver receives is visual. A decrease in visual skills with age could be an important causal or contributory factor in the driving difficulties experienced by the older driver.

Several authors *(2, 6–10)* have reviewed the visual characteristics of the elderly, and it is clear that nearly every aspect of visual performance decreases in old age.

The crystalline lens within the eye shows functionally significant changes with age. It progressively and predictably loses its elasticity, causing a decrease in the ability of the eye to accommodate, or change focus. This loss begins to impair performance of common near-point tasks around the age of 40; typically, compensation must be obtained through reading glasses or bifocals. The loss of accommodation is complete by the age of 60 to 65. The lens also loses its transparency and becomes yellowish with age. This contributes to changes in color vision, decreased light sensitivity, and decreased visual acuity. It also increases light scatter within the eye, resulting in increased susceptibility to disability glare such as that created by oncoming headlights. Cataracts, opacities that develop in the lens of the eye, are usually age related. They obstruct and scatter light and should be removed when the reduction in vision begins to impair performance of normal tasks. After a cataract extraction, the optical power of the lens must be replaced by means of strong spectacles, contact lenses, or intraocular lens implants.

The pupil of the eye becomes smaller with age and loses its ability to dilate in dim light. Consequently, the elderly eye admits less light. This relative deficit is most pronounced in darker conditions. The area of the typical 20-year-old pupil is 12 times larger than that of an 80-year-old pupil *(11)*; thus the illumination on the older retina is only 8 percent as intense as that on a younger retina.

Many disorders of the retina are associated with age. Degeneration of the macular or central retina is more common in the elderly and is referred to as age-related maculopathy (ARM). Central vision is affected by impairments in visual acuity and night vision. Retinal detachments are more common in older eyes and result in the loss of portions of the visual field. Peripheral retinal degenerations are common in the elderly and may cause loss of peripheral vision. Other progressive conditions producing visual degradation include retinitis pigmentosa, degenerative myopia, diabetic retinopathy, hypertensive retinopathy, arteriosclerotic retinopathies, and glaucoma.

Most tests of visual function and performance show functional decreases in visual capabilities with age. In the absence of disease, corrected visual acuity remains relatively constant from ages 20 to 50. After 50, corrected acuity begins to decrease, with a rapid decline after 60 *(12)*. The critical flicker frequency (CFF), the flicker rate beyond which flickering of light cannot be

detected; dynamic visual acuity; and color discrimination show age-related declines *(9)*. Studies of dark adaptation *(13)* show that the elderly have reduced sensitivity to light. Visual field has also been shown to exhibit age-related losses.

Higher-level functions showing age-related decline have recently been reviewed *(2)*. There is evidence of diminished cognitive capabilities, visual spatial judgments, and visually based motor responses. The elderly find it more difficult to give selective attention, especially within a complex array of information. Visual spatial and organization skills show deficits with age. The elderly tend to show deficiency in recalling recently acquired information even though they tend to be proficient at remembering more remote events. Complex problem-solving abilities tend to diminish with age. The elderly may have difficulty in ignoring redundant or superfluous information. All of these higher-level skills are used in driving.

Staplin also presents data from the American Automobile Association that show a 4 percent increase in reaction time for every decade of adult life. Thus, a 70-year-old driver takes 20 percent longer to react than a 20-year-old driver.

The decreasing visual abilities of the elderly may be a significant contributing factor to the decreasing driving ability associated with age. The purpose of this paper is to examine whether current vision standards and screening procedures for drivers are appropriate for identifying those with significant visual disabilities that are unsafe for driving.

CURRENT STATE OF THE ART

Visual Acuity and Visual Field

The primary vision screening test in the 50 states is static visual acuity. The National Highway Traffic Safety Administration (NHTSA) surveyed state visual acuity standards for driving *(14)*. For the best corrected vision and with both eyes open, standards range from 20/30 to 20/60; 41 states use the 20/40 standard *(15)*. Some states have lower acuity standards if the applicant is wearing optical correction or higher standards if there is blindness in one eye.

Many states have a visual field requirement [27 states according to Keltner and Johnson *(15)* and 17 according to NHTSA *(14)*]. The requirements always relate to a measurement of the extent of the horizontal meridian of the visual field, and the required minimum field size ranges from 70 to 140 degrees.

Several states impose stricter visual acuity or visual field standards, or both, for bus or truck driver's licenses. Ten states do not allow individuals with one blind eye to obtain such licenses. A few states also specifically do not allow individuals with bioptic telescope systems to obtain such special class licenses.

Keltner and Johnson *(15)* report that 41 states require visual testing for license renewal.

Visual acuity standards used in other countries are generally similar to the U.S. standards, but the between-country variations are greater than the between-state variations within the United States *(16)*. Some countries use a license plate reading task as the principal visual criterion, following a practice that originated in Great Britain. An acuity level of about 20/33 is required to perform this task. Most countries have a visual field requirement, and many test color vision and some aspects of binocularity.

The American Optometric Association (AOA) and the American Association of Motor Vehicle Administrators (AAMVA), in a joint 1974 publication *(17)*, recommended that a visual acuity of 20/40 be required, either with or without optical correction. They recommended that drivers with two functioning eyes be required to have a binocular visual field at least 150 degrees wide in the horizontal meridian and that drivers with one eye have a visual acuity of at least 20/30 and a visual field of 40 degrees nasally to 75 degrees temporally in the horizontal meridian. Color vision testing was recommended for professional or commercial drivers but not for drivers of private or personal vehicles.

The U.S. Department of Transportation (DOT), NHTSA, and AAMVA also offered in a joint publication *(18)* recommendations for vision standards and testing for drivers. They established six categories of visual acuity, three levels of binocular visual field, two levels of monocular visual field, two levels of ocular motility, and two levels of color discrimination. They recommended that eligibility for license type (passenger, commercial, etc.), the need for periodic reevaluation, and various constraints or restrictions depend on the level of visual ability in each of the specified visual function categories.

The AOA in 1965 adopted a policy that favored stipulating a desired standard of 20/20 or better in each eye, normal binocular vision, no field restriction, no muscular anomalies, and no color vision deficiency. However, their recommended minimum visual standards were 20/40 or better in at least one eye, no double vision, and an intact field of vision of at least 70 degrees to one side and 45 degrees to the other. A driver unable to meet these minimum requirements should not be licensed without a thorough evaluation of his driving skills.

Sign Design

A rational connection may be made between visual acuity and driving performance, because the identification of detail is necessary for making many driving decisions. One visual task that is common and quantifiable is the recognition or reading of signs. Forbes *(20)* reviewed sign design, and Gordon et al. *(1)* cite common sign design standards. A current design rule is that 1 in. of letter height be provided for every 50 ft of recognition distance. This

translates to a visual acuity requirement of 20/23. At least 13 percent of the current driving population (who are principally screened for 20/40 vision) will not have the 20/23 vision for which the signs are designed *(21)*.

Older drivers are more likely to have visual acuity less than 20/23, and furthermore, as a group, they have slower reaction times. Halpern *(22)* presents evidence that the elderly take relatively more time to process signs with symbols than with alphanumerics, suggesting that it may be preferable to use signs with verbal messages for the elderly.

Sign design standards are intended to ensure that displayed information is received in time to allow drivers to make the appropriate response safely. They are based on assumptions involving factors such as expected travel speed, processing time, and reaction time. A significant proportion (about one-sixth) of the driving population has a visual acuity that diminishes this safety margin, and the elderly are disproportionately represented within this group.

Other Visual Measurements

Static visual acuity is the only visual ability specified as a prerequisite for driving by all U.S. states and Western countries, and in all authoritative recommendations. There is strong, but not unanimous, preference for an acuity requirement of 20/40 among the 50 states. Beyond the visual acuity requirement, the various states show a considerable range of differences in their requirements relating to optical correction, visual field, monocularity, color vision, depth perception, diplopia, and the use of bioptic telescope systems and in the provisions for special license categories and for relicensure. As summarized in the NHTSA report *(14)*, seven states have a color vision requirement, three states have a depth perception requirement, one measures eye coordination for lateral and vertical imbalance, and apparently none uses dynamic visual acuity.

RELATIONSHIP OF VISION AND DRIVING PERFORMANCE

The most comprehensive study of the relationship between vision and driving performance was conducted by Burg on over 17,500 California drivers during a 3-year period *(3, 4, 23)*. The age and sex of drivers and annual number of miles driven were recorded. Visual attributes measured on each subject included static visual acuity, horizontal heterophoria, low-light recognition threshold, glare recovery, horizontal visual field, and dynamic visual acuity. The visual data were analyzed in relation to traffic convictions, all reported accidents, accidents recorded by the Department of Motor Vehicles (DMV), accidents excluding those caused by obvious nonvisual factors, daytime

accidents, and nighttime accidents. The significant correlations found between vision and the driving performance metrics were very weak.

A later analysis of the Burg data *(24)* drew some interesting conclusions. No meaningful relationships were found between the accident rates and any of the visual test results for persons under the age of 54. For those over 54, however, both dynamic and static visual acuity showed relationships to accident rates, even though the correlation coefficients were quite small. The horizontal extent of the visual field was not found to be related to accident rates. No significant relationship was found between driving and low-light recognition threshold or glare recovery for any age group, although the glare recovery test was judged to have a marginally significant relationship with driving performance for those over 54.

Following their review of the prior literature and the analysis of the Burg data, Henderson and Burg *(25)* assigned weights to various aspects of driving behaviors and also to each visual function according to its judged importance to each behavior. Their overall weightings suggested that the visual attributes most important in driving are, in ascending order, detection of angular movement, detection of movement in depth, the extent of the useful visual field, static visual acuity, saccadic fixation, and dynamic visual acuity.

Hofstetter *(26)* correlated visual acuity test scores with self-reported accidents of 13,786 drivers. Accident rates for persons with acuity in the lower quartile of the measurements were compared with those for persons with acuity above the median. Drivers in the poorer visual acuity group were twice as likely to have had three accidents in the previous 12 months and 50 percent more likely to have had two accidents. The two visual acuity groups showed no significant differences in their likelihood of having had one accident. These trends persisted across ages. By using records of multiple accidents to identify the accident-prone, Hofstetter has provided the strongest evidence yet available to show a connection between poorer visual acuity and increased propensity for accidents.

Shinar *(27)* also reviewed the literature on the relationship of vision to driving performance. He used an instrument called the Mark II Vision Tester, which was an expanded version of the testing equipment developed by Burg and his coworkers. It measured the following parameters: static visual acuity under standard photopic conditions; dynamic visual acuity; detection-acquisition-interpretation skills; static visual acuity under low-light levels; detection thresholds for movement in depth, angular movement centrally, and angular movement peripherally; the horizontal extent of the visual field; and static visual acuity with glare. This test battery was administered to 890 licensed drivers, and for each driver the accident history was recorded. Static visual acuity under low illumination and dynamic visual acuity were the two attributes most consistently related to accidents. Poor static visual acuity under

low illumination conditions was particularly related to involvement in nighttime accidents. Detection of central angular movement was third in the strength of relationship to accident involvement. Correlation coefficients were calculated separately for daytime and nighttime accidents and also for the different age groupings for each of the nine categories of visual performance. All of the attributes tested were found to be significantly correlated with accident rates in at least one of the subtests, and none of the vision tests correlated in all of the subtests.

Hills *(28)* suggested that the poor correlations found between vision measurements and driver accident rates could be attributed to many factors, including compensatory behavior by drivers. He presents the view that higher-level perceptual errors or misjudgments as related to factors such as inattentiveness, overconfidence, and fatigue are the major cause of accidents.

Davison *(29)* studied vision in relation to the reported accident records of 1,000 randomly stopped British drivers. Reported accident rates were found to have significant correlations with monocular visual acuity, binocular acuity, and hyperphoria. The number of miles driven was not reported; thus the more meaningful measurement of accident rate was not available. Visual acuity was more strongly associated with accident rates for drivers 55 and over, and the association was stronger for the right-eye visual acuity than for the left. A study of U.S. drivers *(30)* showed that the left-eye visual acuity was more strongly associated with accident rates. This suggests that the visual acuity of the roadside eye is most important. However, it is difficult to provide a convincing rational explanation for this proposition. The roadside roof-support pillar does obstruct vision, with the obstructed regions being different for the right and left eyes. Consequently, within the field of the front windshield, there is a region (often about 5 degrees wide and located about 25 to 35 degrees off center) that can only be seen by the nonroadside eye. A similar small region within the side window and just behind the roof-support pillar is only visible to the roadside eye. If poor visual acuity in the roadside eye does indeed create a significant hazard, then it might suggest that discernment of detail within the region near the roof-support pillar is of high importance. A more likely explanation is that profound losses of vision in the roadside eye may effectively reduce the roadside visual field for object detection, in which case the association should be thought of as resulting from a functional field deficit rather than from a simple difference in resolution between the roadside eye and the other eye.

Standard visual acuity measurements are made with high-contrast targets. Studies by vision scientists and clinicians indicate that such high-contrast visual acuity scores are not highly reliable predictors of the sensitivity to lower-contrast targets *(31)*. Contrast sensitivity may be measured by a number of means, some of which involve the detection of striped patterns of various

contrasts and spacings presented on either video or printed displays, whereas other tests require the reading of low-contrast visual acuity charts. A prima facie case can be made that many of the detection and recognition tasks associated with driving are strongly dependent on the ability to discriminate small contrast differences in larger objects or features. Contrast sensitivity is arguably more important than high-contrast visual acuity for tasks such as detecting pedestrians and other vehicles, seeing the edges of the roadway, and recognizing undulations or irregularity in the road surface and many other features. It is known that contrast sensitivity decreases with age *(32)*, but there is no direct evidence associating reduced contrast sensitivity with traffic accidents.

Burg *(3, 4, 23)* found dynamic visual acuity to be more strongly related to accident rates than static visual acuity. Dynamic visual acuity involves the discrimination or recognition of detail on a moving target and might be expected to be more relevant to the driving task than the identification of detail on a stationary target as measured in static visual acuity tests. Dynamic visual acuity is also known to decrease with age *(10)*.

Because identification of objects within the peripheral visual field is a necessary task for a driver, it might be expected that deficits in peripheral vision would correlate with driving performance. However, the majority of the published studies show no such correlation *(33)*. Most of these studies involved nonstandard perimetric techniques and inadequate controls over the subjects' fixation; furthermore, only the extent of the horizontal meridian of the visual field was considered. A notable exception is a study by Johnson and Keltner *(34)*, who used an automatic visual field screener (Field Master model 10-PR) to gather data on 10,000 volunteer subjects (20,000 eyes). Drivers with binocular visual field loss had accident and traffic violation rates that were twice as high as those for drivers with normal visual fields. Drivers who only had monocular visual field loss showed driving records similar to those considered normal. Their screening procedure presented 78 stimuli located at sites between 5 and 60 degrees within the visual field, and their testing was performed on each eye separately. The incidence of visual field loss was 3.3 percent, in general agreement with the 1 to 8 percent found in other studies *(33)*. More than half of the subjects with visual field losses had been unaware of their deficits. Johnson and Keltner *(34)* reported that the average testing time per eye was under 2 min, including setup time.

Visual field reductions can be caused by age-related decreases in retinal illumination and perhaps some contribution from a reduction in retinal sensitivity. Visual disorders such as glaucoma, degenerative myopia, diabetic retinopathy, and retinal detachment may affect the visual field and are more prevalent in older persons.

Individuals with one functional eye have a restricted visual field. In normal binocular vision, the horizontal visual field is between 170 and 200 degrees

wide, whereas the monocular horizontal visual field is only 130 to 160 degrees wide. The more important field constraints imposed by monocular vision are the limitations of the visual field to about 50 degrees (instead of 90 degrees) on the side of the blind eye and the enlargement of the regions obscured by roof pillars, dangling ornaments, and other hardware features of the vehicle. In binocular vision each eye compensates for the physiological blind spot of the other, whereas the monocular driver experiences a true loss.

In a group of drivers with high accident rates Keeney *(35)* found that 8 percent were monocular. Surveys of patients from private optometric practices found only a 2 percent incidence of one-eyed individuals. Liesmaa *(36)* considered a group of drivers who had been observed showing dangerous driving behaviors as judged by observers from a patrol car. A control group of apparently good drivers was similarly selected. The incidence of monocular vision was three times higher in the group driving dangerously than in the control group. In addition to the visual field restriction, monocular drivers also suffer from a loss of stereopsis or binocular depth perception. Keeney and Garvey *(37)* recommend that monocular individuals not be licensed for professional or commercial driving. Both the Keeney and the Liesmaa studies have substantial design or reporting limitations, or both.

Less light falls on the retina in the older eye because of the smaller pupil and the decrease in transparency of the ocular medium. Consequently, there is a decrease in relative light sensitivity with age. Although night driving is essentially a mesopic task, age-dependent differences in night driving performance must be expected on the basis of studies of the dark adaptation process. For detection tests on the dark-adapted eye, 10 times the light is needed by a 60-year-old compared with a 20-year-old *(13)*. MacFarland's data indicate that between the seventh and ninth decades there is a further 10-fold decrease in the absolute threshold for the dark-adapted eye.

Kline *(10)* reported that older drivers believe that low illumination causes functional difficulties. Older drivers are more likely to judge their dashboard instruments inadequately illuminated and are also more likely to avoid nighttime driving if they have the option. Steward et al. *(38)* surveyed 2,000 persons seen for optometric examinations and found that the proportion of drivers reporting visual difficulty with nighttime driving was virtually independent of age. However, they also found that after age 70 there was a substantial increase in the proportion of drivers electing not to drive at night for vision-related reasons.

It has been argued *(39)* that protanopic and protanomalous drivers are at some disadvantage because they are relatively insensitive to red light. Consequently, they would be more likely to have poorer responsiveness to red signal lights, tail lights, and brake lights. However, color vision defects have not been shown to be associated with higher accident rates.

Older persons are also more susceptible to intraocular light scatter and consequently have more difficulty with disability glare. This is a particular problem when driving into the sun or at night with oncoming headlights. The bright light is scattered across the retina and produces an effective veiling luminance that decreases the visibility of other objects in the field. Pulling et al. *(40)* showed that the glare threshold substantially worsens with age. However, the relationship of disability glare sensitivity to accident rates remains largely uninvestigated.

The ability to properly judge distances and the speed and distance of an approaching car could appear to be related to driving performance. Stereoscopic depth perception, however, has not been shown to correlate with accident rates *(27)*. Kline *(10)* reviewed studies that showed that the ability to judge depth declines with age as does a driver's ability to judge the speed and distance of an approaching car.

Vision is obviously important in driving, because it is the primary sensory input used for the task. The visual skills required to perform particular driving tasks are numerous and varied. However, statistical relationships between visual measures and driving performance measures such as citations and accident rates are weak. Other factors such as windshield dirt, windshield damage, dangling toys, distractions, camouflage, solar glare, obstructed signs, worn lane lines, and traps are likely contributory or causative agents. Accidents are relatively rare occurences and result from a combination of circumstances and factors. It is not surprising that correlations between vision measurements and accident rates are weak. Most individuals with very poor vision have already been denied licensure, so they are not represented in these studies, which dilutes the correlations. Until and unless it can be convincingly shown that a particular measure of the more exotic visual abilities bears a strong correlation to safe driving performance, it is the common clinical measures of vision that are likely to remain as the bases for driver's licensure criteria.

BASES FOR VISUAL STANDARDS AND SCREENING PROCEDURES

The primary goal of setting vision standards for drivers and establishing vision-screening programs is to improve safety and driving efficiency and, in particular, to reduce accidents, injuries, and deaths. A subsidiary benefit of vision-screening programs is that individuals in need of vision or eye care may be identified, and with proper professional attention their problems may be treated or rectified so that they may optimize visual performance for driving and other tasks.

For most people in today's society, driving is almost essential for work, social and recreational activities, and the daily needs of life. This is equally

true for the elderly. License denial cannot be taken lightly; it can be a severe restriction on a person's ability to participate in society. The setting of standards is necessarily a balancing process, weighing the risk to public safety against the individual's freedom to drive. In the establishment of visual standards for driving and the procedures for applying those standards, there are several major issues that require consideration.

First, the impairment of what visual attributes is associated with unsafe driving performance? Ideally the visual attributes that are specifically demanded for driving licensure should be irrefutably associated with accident rates or some other index of driving performance. However, even if there is no clearly demonstrable association, a strong prima facie case can be made for the claimed relationship. It is not essential that the relationship always be shown to be a causal one. A causal relationship should be required for denial of licensure, whereas an associational relationship may only justify referral for a professional opinion. For example, there is evidence *(34)* that visual field defects are associated with reduced driving safety. A substantial proportion of the visual field defects are a result of glaucoma, in which not only losses of visual field occur, but also of contrast sensitivity, night vision, and glare sensitivity. It is conceivable that these other visual characteristics may be more relevant to accident causation than are visual field defects. Nevertheless, this possibility does not dilute the value of visual field testing to identify drivers who are at risk because of impaired visual function due to glaucoma.

Second, at what level should the visual criterion be set? It is almost inevitable that some arbitrary judgments will be made about the most suitable level of performance at which to set the minimum criterion required for driving. Regardless of the strength of the evidence that might support the chosen mimimum standard, it is virtually certain that there will not be sufficient justification for a single and absolute cutoff point. If, for example, there were a 20/40 standard, it would be unfair to allow a debilitated, inattentive person with 20/40 to drive and deny licensure to a fit and alert person whose visual acuity is only marginally below 20/40. Any practical and rational vision-screening program should allow individual consideration for persons whose visual capabilities fail to meet the required standards.

Third, what vision-screening tests should be used? For any visual attribute for which a standard has been set, there should be a reliable and valid means of measurement that will clearly establish whether the standard has been met. For example, Cole *(41)* points out that measurements of the rate and extent of dark adaptation are not reliable because one individual can show variations similar in magnitude to the variations among individuals. The chosen vision-screening tests should be well established and accepted, give repeatable results, and provide a means of consistently identifying individuals whose visual capabilities fall short of the required standard.

Fourth, will the imposition of the standard cause a real change in the driver population? If the standard is excessively lenient, only the few with very poor vision will be eliminated from driving. It might even be expected that most of those in this category would voluntarily cease driving regardless of any statutory requirements. However, Guest and Jennings *(42)* in a survey of a clinical population reported that more than 40 percent of those over 60 refused to obtain correction that would improve their vision to a level that would meet or exceed the driver's license standard. If the standard only serves to screen out persons with extremely uncommon vision deficiencies, its impact on the overall population will be very small and the relative cost and benefit of screening the entire driving population to identify merely a few should be examined. The imposition of a required standard for visual acuity can affect the character of the driver population by identifying many whose vision can be significantly improved by proper refractive correction and by eliminating those who, even with the best correction, cannot achieve minimum resolution standards.

Fifth, do the safety benefits justify the costs of administering the standard? There are costs associated with the administration of any visual standard. Records must be kept, equipment with adequate backup provisions must be available, staff must be trained, and the usual overhead costs must be met. There should be certainty that the exclusion of drivers on the basis of vision-screening examinations will cause a significant reduction in costly traffic accidents to justify the whole process on a cost basis. A sometimes overlooked cost in applying vision-screening programs is that of the applicant's time. The time taken by the applicant in waiting for and participating in the vision-screening process should not be excessive, and to this end, the vision-screening stations should be conveniently located.

Sixth, are there other alternatives to the imposition of the standard? Cole *(41)* illustrates that engineering changes may sometimes be a cost-effective way of compensating for visual deficiencies with this example. Some red, green, and amber signal combinations could present difficulties for persons with inherited red or green color vision defects and possibly justify exclusion of the 8 percent of the male population who have such disorders. However, the color characteristics of the signals have been modified so that they are more distinguishable *(43)*. Adding redundant information such as shape or order differences is another simple, cost-effective way to facilitate signal identification. About one-eighth of the men with color vision disorders have a loss of sensitivity to red light. Increasing the luminance of the red signals in warning signs and in brake and tail lights would reduce the functional disadvantages of this particular type of color vision deficit.

Finally, should failure to meet the standards require immediate exclusion from the driving population, or would it be more appropriate to impose

selected restrictions and constraints? This is particularly applicable to the elderly, who have a greater incidence of vision defects. Persons who fall short of meeting a required standard should be given an opportunity for special consideration. Previous driving experience, anticipated driving needs, previous driving record, other physical or sensory disabilities, stability of the causative pathological condition, opinions from eye care professionals, and driving performance capabilities judged by experienced evaluators are all factors that could be taken into consideration to decide whether a special driver's license could be provided. Such licenses could have a range of constraints or restrictions.

Factors that might influence license denial or restriction:
- Driving tests
- Driving experience
- Driving record
- Driving needs
- Anticipated driving patterns
- Causative visual disorder
- Prognosis of visual disorder
- Variability of vision
- Opinions on visual abilities
- Other visual disabilities
- Other sensory-motor disabilities

Special conditions:
- Monitoring of accidents
- Monitoring of violations
- Renewal frequency
- Vision report frequency
- Driving test frequency
- Mirror requirement

Restrictions:
- Time of day
- Visibility condition
- Route
- Speed
- Purpose
- Distance from home
- Vehicle category
- Bioptic telescope requirement

Restrictions that could possibly apply to all special-consideration licenses might regulate frequency of renewal, of vision evaluation, or of driving performance evaluation. Constraints that could depend on individual considerations could be restricted times for driving, routes, speeds, and special mirror requirements, passenger limitations, and vehicle type.

IMPLEMENTATION ISSUES

Authorities issuing driver's licenses must keep their policies and practices under review. Careful consideration should be given to the cost and benefit relationships associated with any contemplated changes. On the benefit side of the equation, the overriding broad question is "How will changing the visual standards affect the vision characteristics of the driving population and will this affect the safety or efficiency of driving?" On the cost side, the broad key issues are "What are the equipment, space, personnel, and administrative costs associated with changing standards or practices? And how are these balanced by the costs associated with anticipated changes in accident rate and traffic efficiency and on the personal and societal costs of removing selected individuals from the driving population?" Assigning monetary values to the different components of such a cost-benefit analysis is usually difficult and imprecise, and the costs and benefits associated with implementing changes are highly dependent on the existing practice. In any consideration of changes of screening practices it is important that the range of relevant key issues be identified.

Most states have between 50 and 100 or more examining offices, and most of these have more than one vision-testing station. The cost of new vision-testing equipment would necessarily be a large factor in implementing new screening practices. It would also be necessary to have backup equipment. Most states currently use wall-mounted acuity charts or have Telebinocular, Orthorater, or Keystone vision screeners. It is easiest to implement changes in vision-screening procedures if new tests can be performed on the existing equipment. If the vision-testing procedures require special conditions, such as a darkened room, this could be very costly. Probably the largest costs, however, would be those related to the time required to perform the testing. If additional testing time is required, more office space and more employee time should be acquired. Unless the additional vision tests are simple, there would need to be staff training and upgrading.

If the implementation of additional screening procedures resulted in significant reduction in accidents, the overall savings might be sufficient to offset the increased costs of screening. Although it is difficult to place a dollar value on accidents, especially those involving injury or loss of life, the severity and frequency of accidents are high enough to warrant substantial expenditures to prevent them.

It becomes logical to try to establish a mathematical equation that could be used to determine whether changes in vision screening would be cost-effective. The real costs of administering the screening tests to each driver should be determinable (although reasonable estimates have not been found). The savings achieved by performing the screening could be determined by multiplying the proportion of drivers who would fail the screening, the total number of drivers, the risk factor that those failing would have accidents, and the average cost per accident (estimated at $800 by the California DMV in 1987). The large unknown in the equation is the risk factor. Such data are not currently available, nor are there prospects for having them in the near future.

However, there is more than just one piece of missing data—an exact equation would be considerably more complex. Some of those who fail the screening may become licensed after professional eye treatment. Is their accident risk rate different from the normal one? Some may be given restricted licenses. What are the effects of restricted licenses on accident risk rates? Some may be denied licensure. What are the societal costs of restricting or denying licensure to a segment of the population, many of whom would not have accidents if they were licensed? These costs involve lost productivity of the individuals as well as inconveniences imposed by lost mobility. It is difficult to assign monetary value to the quality of life. If a group were screened and identified as having an accident risk rate 10 times that of the entire population, they would probably choose to be licensed and take their chances, if given the opportunity.

The principle of vision screening, however, is to identify those who need further testing or who should not be licensed, but with the minimum number of tests. For additional vision testing to be included in licensing procedures, there should be evidence that the function tested is substantially related to driving performance or that it would identify disorders or defects that would warrant license denial or referral for professional opinion.

Vision tests that have been advocated because they show some weak correlation with driver performance often do not give repeatable measurements or are not currently accepted by the clinical eye care community. It would be unreasonable to deny licensure on the basis of such tests, and it certainly would not be defensible in court given the current state of knowledge. A court challenge could be mounted on grounds of discrimination based upon a physical handicap. The burden of proof would be on DMV authorities and experts to show that the measure of vision was related to the driving task and that the applicant was determined unable to drive satisfactorily on the basis of that measure. Current evidence does not provide much support for such arguments. It would be appropriate for the applicant to bear the cost of the special evaluation and the administration of any restrictions or special conditions.

MERITS OF VARIOUS ASPECTS OF VISION SCREENING

Visual Acuity

Visual acuity is the most commonly accepted clinical measure of visual performance. It provides reliable and repeatable results, and standards have been set for its measurement *(45–47)*.

A visual acuity requirement for driving can

- Encourage some individuals to seek an optical correction before appearing for the vision test when applying for their license,
- Identify drivers whose vision is poor (below the prevailing standard) without correction but can be improved to near normal with appropriate correction, and
- Identify those whose vision is below the prevailing standard even when they wear the best optical correction that is currently available to them.

Individuals failing to meet the standard should be referred for optical correction. For most of those referred, an appropriate optical correction can improve visual acuity to 20/20 or better. These individuals then become eligible for a license requiring them to drive with corrective lenses. A small proportion of those referred may have vision not correctable to the standard; for these, special consideration is indicated. This group will be predominantly elderly and have diseases associated with aging such as cataracts, glaucoma, maculopathy, and retinopathy. A license could be issued with or without special restrictions, or it could be denied. Usually, the vision loss is permanent. Only occasionally does medical intervention (e.g., cataract surgery) enable a return to adequate visual status.

The number of people whose driving vision can be improved because of a visual acuity screening program depends on the level at which the standard is set. Data from the U.S. Department of Health, Education, and Welfare (HEW) *(21)* survey on visual acuity provide a means of estimating the impact of visual acuity standards for driving. Table 1 has been prepared using data from this survey. These figures represent the best binocular visual acuity when the usual visual correction is worn.

The data in Table 1 indicate that 3.5 percent of the adult population would fail a 20/40 visual acuity standard. A tighter standard of 20/30 would fail 6.9 percent, and a looser standard of 20/50 would fail 2 percent. The failure rate increases substantially for the older age groups. Had this survey included the 75-and-over age group, the failure rate would have been even higher and the increase with aging would be even more pronounced.

The principal conclusions derived from the analysis of Table 1 are supported by the results of a study by Rice and Jones *(44)* on an experimental

TABLE 1 IMPACT OF VISUAL ACUITY STANDARDS

	Percentage Below by Visual Acuity Level							
Age Group	20/20	20/25	20/30	20/40	20/50	20/70	20/100	20/200
18-24	12.5	6.7	3.3	2.4	1.9	1.4	0.8	0.1
25-34	15.7	5.6	2.6	1.5	0.6	—	—	—
35-44	14.7	4.8	2.1	0.8	0.5	0.1	—	—
45-54	28.9	14.0	6.7	3.2	1.9	0.7	0.3	—
55-64	43.9	20.8	10.4	4.5	2.6	0.7	0.5	0.2
65-75	68.0	40.3	26.0	14.1	6.8	3.0	1.4	1.0
Total	26.8	12.9	6.9	3.5	2.0	0.8	0.4	0.1

vision-screening program for driver's license renewal in Oregon. There had not previously been a visual requirement for renewal in that state. This study was conducted at selected DMV offices in which applicants for license renewal had a vision screening that included tests of visual acuity, color vision, depth perception, binocular vision, and visual field. The program was publicized so that those wishing to avoid the vision screening could visit a nonparticipating DMV center. This was an acknowledged source of under-referral in the study. Rice and Jones found that 81 percent of 454 applicants passed the vision-screening test, either without glasses or with glasses if they had been so required by their original driver's license. About one-fourth of those who passed already had a "with corrective lenses" restriction on their original license. Of the 18.9 percent who failed the vision test, the majority (9 out of 10) had a "with corrective lenses" restriction imposed without referral because they had developed a need for and had acquired a refractive correction since receiving their original license. Overall, only 2.4 percent of the sample population was unable to pass the vision screening; these were referred. Of those referred, 88.7 percent failed the visual acuity test, 10.3 percent failed the binocular vision test, and 0.7 percent (one subject) failed the visual field test. The visual acuity standard in Oregon is 20/40 and the 2.4 percent failure rate is reasonably consistent with the 3.5 percent referral rate expected from the HEW survey statistics, especially considering that there was probably an underreferral rate in the Oregon study and that some of the 3.5 percent in the HEW survey would not appear for a driver's license.

In broad terms, one can expect about 60 percent of the driving population to pass a 20/40 standard without corrective lenses. About another 37 percent will pass provided that they use their current glasses or contact lenses, leaving about 3 percent requiring referral. Of those unable to achieve 20/40 in the screening examination, a large proportion (an estimated four-fifths) will be able to obtain a correction that will return them to driving with a visual acuity of 20/20 or better. A more stringent standard of 20/30 would fail almost 7 percent of applicants and most (nine-tenths or more) of these would return to driving with excellent visual acuity.

Hofstetter's analysis *(26)* provides empirical evidence that reduced visual acuity is associated with repeat accident rates. This supports the prima facie case that driving safety would be enhanced if drivers improved their vision through the use of appropriate corrective lenses. In our view, the principal purpose of the visual acuity screening program should be the improvement of visual acuity, not the elimination of relatively a small number of drivers who have irreparably reduced visual acuity.

A rational connection may be made between visual acuity and driving performance, because the identification of detail is necessary for making many driving decisions. One common and quantifiable task is the identification of information on signs. Signs are usually designed for the driver with 20/20 vision, and theoretically a visual acuity of 20/23 is required to read traffic signs at the intended distance.

Dynamic Visual Acuity

Although most studies have shown dynamic visual acuity to be more strongly related to accident rate than other visual attributes, the correlation is not strong enough to justify its inclusion as a driver vision standard given the numerous difficulties in testing.

The dynamic visual acuity task is complex, and a variety of decisions must be made about the selection of test parameters. These include the size and contrast of the test targets, the rates of movement, whether the eyes should be stationary or following the target, whether the target trajectory should be circular or straight, what retinal eccentricities should be tested, and whether target location, trajectory, or speed should be predictable to the subject. Although a considerable amount of research has been performed on dynamic visual acuity, it has not led to standardized testing procedures accepted by eye care professionals. The repeatability of dynamic visual acuity measurements is also poor. Without a standardized data base or broad-based experience with dynamic visual acuity testing, the imposition of a standard cannot be justified. Furthermore, it is not clear whether clinical treatment or training could improve dynamic visual acuity. In our view, it should not be seriously considered until the knowledge base becomes substantially firmer. If an applicant were denied licensure on the basis of a test of dynamic visual acuity and chose to appeal, it would be difficult to provide evidence to justify the denial.

Visual Field

Peripheral vision is obviously relevant to driving. In the driving situation, it is the extent of the visual field when both eyes are open that is of greatest

relevance. Many states apply a vision standard for the horizontal extent of the visual field. In the most common screening test, a large (20- to 40-mm) white test object is presented a short distance away against a dark background. The monocular visual field normally extends 100 degrees temporally and 60 degrees nasally *(48)*. When both eyes are open, the horizontal visual field includes 100 degrees to the right and to the left, a total width of 200 degrees.

Subtle deficiencies or local depressions of sensitivity in the visual field are probably not of major concern in the driving task, but absolute or extensive losses are. The patterns of peripheral visual field loss depend on the underlying visual disorder. When vision is extremely reduced in one eye, regions of the total visual field are functionally inaccessible and this creates a potential driving hazard. If one eye is nonfunctional, the visual field to that side is limited to about 60 degrees. Furthermore, obstructions such as the roof-support column on the driver's side and the rearview mirror become significantly more obtrusive if one eye is sightless. It could be argued that one-eyed drivers should receive advice and instructions on their limitations and should have better mirror systems that would partially compensate for their visual field deficiency.

Some conditions such as retinitis pigmentosa and glaucoma begin to cause visual field losses in the midperipheral region; typically, these blind regions progress to involve most or all of the peripheral field so that later only central "tunnel vision" remains. Retinal detachments and peripheral retinal degenerations also cause visual field loss. Hemianopia is the loss of half of the visual vield, most commonly caused by cerebral vascular accidents or other cortical disorders and similar in extent for both right and left eyes.

Some age-related reductions in measured peripheral visual field result from the effect of small pupils, cataract, or perhaps a generalized decrease in retinal sensitivity. Individual variations may be substantial *(9)*. The light sensitivity of the 80-year-old eye relative to that of the 20-year-old eye has been shown to be reduced by more than 2 log units (100-fold) in scotopic conditions and by 1 log unit (10-fold) in photopic conditions *(13)*. This suggests that an 80-year-old may be functionally equivalent to a 20-year-old wearing welding goggles with 1 to 10 percent transmission. (Even very dark sunglasses transmit 15 percent.) This general reduction in light sensitivity can reduce the overall width of the measured visual field as well as create obvious difficulties with night vision.

Defective visual field is related to accident rates. The most important evidence comes from Johnson and Keltner *(34)*, who measured visual sensitivity in multiple locations within the visual field using a standardized clinical instrument. They showed that binocular visual field losses were related to accident rates. Simpler tests that measure only the horizontal extent of the visual field have not yet shown such connections with accident rates.

Johnson and Keltner's evidence indicates that it may be desirable to make more detailed measurements of visual field, but this would involve additional screening and the purchase of relatively expensive equipment. However, the cost factor and the speed and ease of using these instruments have recently improved. Sensitive measurement of the horizontal meridian is simpler and might be sufficient to identify the major field losses discussed above. Until further evidence is available, we recommend screening the visual field in the binocular horizontal meridian.

Monocularity

Individuals who are monocular have a decreased functional field of vision and also lack stereopsis. Both of these losses must be considered potentially detrimental to driving. However, a fairly large number of monocular individuals [2 percent of a clinical population *(35)*] are currently eligible for a license, and it would require strong evidence to deny licensure to such a large group.

Monocular individuals can be easily identified by testing the horizontal visual field or measuring monocular visual acuity. The cost of identifying these individuals is negligible. Monocular drivers should be advised of their problem and counseled on hazard avoidance, and an outside rearview mirror on the same side of the car as the nonfunctional eye should be required.

Night Vision and Glare Sensitivity

Decreased visual sensitivity associated with aging reduces night vision, making it more difficult to distinguish objects in dim light. Furthermore, glare caused by scattering of light by the lens or other ocular tissues causes a veiling of vision, which makes it more difficult to detect objects or discern detail, especially if the contrast is low. The elderly are particularly vulnerable to glare and they have reduced contrast sensitivity and special difficulties in dim illumination.

Standardized instrumentation is not currently available for the measurement of visual acuity at low-light levels. Although it is easy to put an acuity chart in a room with variable lighting, it can be expensive and inconvenient to set aside a space and to properly control the lighting. For a valid measure of visual performance in dim light to be obtained, the person being tested would need to adapt to the dark conditions for several costly minutes. These costs could be substantial and should probably be borne by the driver.

Individuals who are known to perform poorly on tests of glare or night vision should be considered for night-driving restrictions. However, until more is known about the measurement of glare sensitivity and night vision

and standardized clinically accepted instrumentation becomes available, it is our view that these aspects of vision should not serve as licensure criteria.

Color Vision

Eight percent of the male population and about 0.4 percent of the female population have some form of congenital color vision deficiency. Of the men, three-fourths have a mild form of deficiency in which one of the three cone systems has reduced sensitivity and the ability to identify certain gradations of color is reduced. Two percent of the male population is missing one of the cone systems. One percent is missing the "green" cone system (deuteranopia) and 1 percent is missing the "red" cone system (protanopia). These individuals have more severe color vision difficulties and are unable to distinguish some basic colors such as red, orange, yellow, and green. Protanopes have a significantly decreased sensitivity to light at the red end of the spectrum, so reds appear darker and are more difficult to detect.

Color vision does not appear to be a major factor in accident statistics. Traffic signals have been standardized so that the green signal is a blue-green and therefore distinguishable from the red and yellow signals by the dichromat *(43, 49)*. The protanope's decreased sensitivity to red can reduce the detectability of red traffic signals *(50)*. The color coding of road signs is redundant when meaning is also conveyed by sign shape or location. There is little justification for using color vision to restrict or deny driver's licenses, but colored signs and signals and visual redundancy should be used to assist those with color vision defects. There might be some merit in screening for color vision at the time of initial licensure to advise those who fail of the difficulties that they might experience. However, the cost benefit would be small.

Double Vision

Double vision, or diplopia, is a potential hazard in driving. Diplopia is most commonly caused by strabismus, a misalignment of the two eyes. Most strabismics suppress the vision of one eye and hence do not experience diplopia. There are special problems for intermittent strabismics, who only experience diplopia when tired, after drinking alcohol, or when viewing a scene with poor fusion cues (such as when driving at night). Some troublesome diplopia problems occur in strabismus secondary to trauma. The resultant visual confusion can be very debilitating at first, but individuals usually learn to pay attention to only one of the images and to ignore the other.

Constant diplopia is not common. Those who have a recent onset of diplopia probably voluntarily abstain from driving during their initial adjustment period when confusion is most troublesome. Screening for diplopia is not likely to be cost-effective.

Bioptic Telescope Systems

A bioptic telescope is a small telescope mounted within a spectacle lens so that the wearer may view through it when it is necessary to discern detailed objects such as road signs. In most cases, the bioptic telescope is placed in front of the better eye and mounted high within the spectacle lens to be above the normal view of the roadway. A driver wishing to inspect distant detail (such as a sign) tilts his head forward about 20 degrees in order to direct the telescope toward the object of interest. After viewing through the telescope, the user lets his head resume its usual position during driving, with the telescope up and out of the way. When the driver is observing through the telescope, he keeps the other eye open. The eye using the telescope will inevitably have an annular scotoma, or blind region, as a result of the magnification. However, the region occluded for the eye with the telescope will be visible to the other eye.

The rationale for allowing drivers to wear bioptic telescopes is that higher resolution is important for specific tasks such as the reading of signs. Bioptic telescopes should be recognized as devices that can be engaged intermittently as needed to enable the user to see finer details, such as those in road signs. Driver orientation and the detection of traffic obstacles, pedestrians, other traffic, and roadway markings are all visual tasks that do not directly demand high resolution. Contrast sensitivity and visual field could be more important for many of these navigational tasks.

Bioptic telescope wear is currently permitted in 22 states, but it remains a matter of contention *(51, 52)*. There is evidence that in California the bioptic-wearing driver population has an accident rate higher than the state average, but Kelleher *(53)* points out that their accident rate is lower than that of other high-risk driver subgroups such as medically impaired drivers (excluding those with visual impairments) and very young drivers. If prescribed and used appropriately, bioptic telescope systems should not present any additional hazard, but they should enable some visually impaired users to perform better at some occasionally encountered visual tasks associated with driving.

Frequency of Screening

Keltner and Johnson *(15)* reported that 41 of 50 states plus the District of Columbia and Puerto Rico require vision screening for license renewal. The frequency of renewal ranges from 2 to 10 years, with 4 being the most common.

Vision screening should identify those who have impaired capabilities due to correctable or uncorrectable disorders. The most common cause of visual acuity loss is uncorrected refractive error. Many with myopia (nearsightedness) show a slow, continuing increase in the magnitude of the myopia.

Astigmatism tends to change toward an increasing against-the-rule astigmatism with age. For young adults with hyperopia (farsightedness), clear vision can often be achieved by the exertion of accommodative focusing power. But as accommodative function decreases with age, the ability to compensate for hyperopia progressively reduces. After age 50, the likelihood of significant refractive error increases, and, furthermore, this is more likely to be of functional significance because of the lack of accommodative flexibility to compensate.

Periodic vision screening obliges a substantial number of drivers to obtain eye care and to achieve significant improvement in their visual resolution abilities. It could be argued that for younger drivers (for example, below age 45), less frequent vision screening might be justified (perhaps every second license renewal). For older drivers for whom refractive error changes are more likely and eye pathology is more prevalent, it would be prudent to test vision at each driver's license renewal (typically every 4 years) and perhaps even more frequently for those over 70.

Vision screening at renewal becomes more effective for older drivers. However, if vision screening were required at renewal only for those beyond a certain age, this would represent a form of age discrimination that might not be permitted by some state laws.

VISION-SCREENING POLICY DECISIONS

All driver's license authorities administer some vision-screening programs, and they should periodically review the purpose and effect of their programs and consider changes that might be made to achieve more effective and economical outcomes. It should at first be recognized that screening visual acuity is liable to have much more impact on the vision characteristics of the driving population than screening any other visual function.

Tests of dynamic visual acuity, contrast sensitivity, and glare sensitivity can identify individuals with questionable visual fitness for driving. Rarely is there an opportunity to rectify deficiencies in these visual functions and return vision to normal. Refractive error may be a contributing factor to deficits in these functions, but a visual acuity test alone is sufficient to identify such refractive error. There are no adequate epidemiological data on the prevalence of significantly impaired dynamic visual acuity, contrast sensitivity, or glare-sensitivity, in the absence of an associated loss of visual acuity. Certainly such a deficit can occur, but until there is respectable evidence of it or opinion to the contrary, it should be considered a rare occurrence. For these three aspects of vision, there is currently insufficient information to justify any particular standard for license denial. There are no well-established and accepted test procedures, and there is inadequate evidence that tests of these functions could

economically identify significant numbers of individuals who should not be eligible for a normal driver's license. Even if there were cost-efficient tests, we would expect that relatively few individuals would actually be denied licensure as a result of substandard performance on these tests, although some might be given a specially restricted license.

In contrast, visual acuity screening can identify many drivers whose vision may be rendered normal by the simple use of corrective glasses or contact lenses. Figures 1 and 2 show models of the screening process for visual acuity and for other visual functions. Most who fail a visual acuity screening can be referred through the "clinical shunt," obtain an optical correction, and return to the driving population with much improved acuity and a license with a simple "with corrective lenses" restriction. This type of screening can also identify individuals with visual acuity loss that is not correctable to normal; such persons should be given individual evaluations and be considered for license denial, a special restriction, or even an unrestricted license.

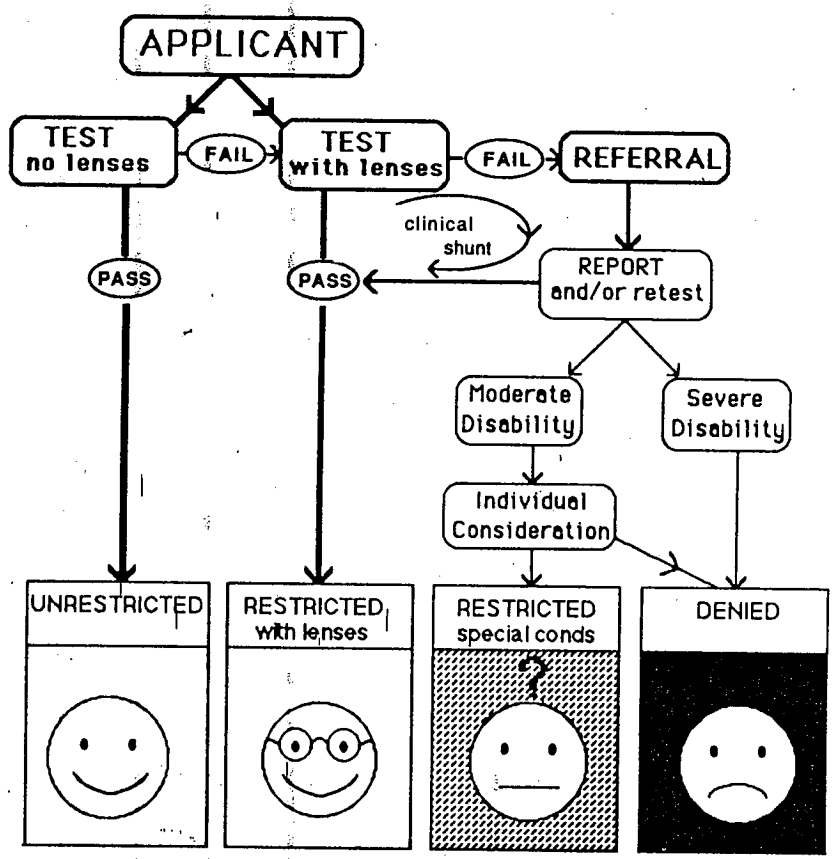

FIGURE 1 Screening visual acuity.

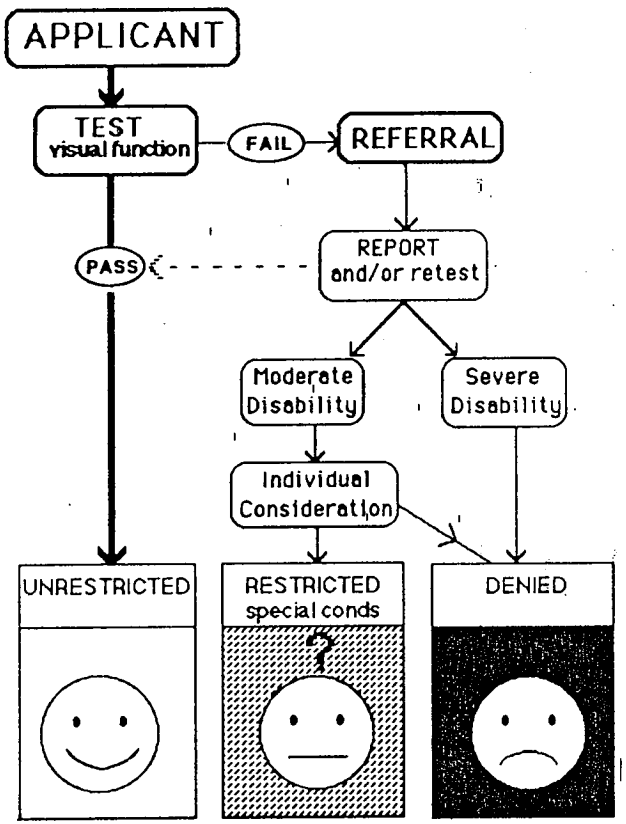

FIGURE 2 Screening other visual functions.

The stringency of standards clearly affects referral rates. Tightening the visual acuity standard of 20/40 to 20/30 would have the effect of doubling the referral rate. Consequently, more individuals would be obliged to obtain corrective lenses and their vision would usually be improved to 20/20 or better. Tightening the standards for any of the other visual functions would cause more individuals to be subjected to the special consideration procedures required in making decisions regarding license denial or restriction. Slackening of standards would reduce referral rates. This would mean that fewer people would be obliged to improve their vision and fewer would be considered for denial or special restriction. For all visual functions that might be included in a screening program, referral rates would be substantially higher for the older age groups. For visual acuity, at least, 70-year-olds are likely to have referral rates that are about 15 times higher than those of young adults (see Table 1).

RECOMMENDED DRIVER VISION SCREENING AND STANDARDS

Visual Acuity

The 20/40 visual acuity standard is the most commonly accepted, and we recommend its retention. Because individuals drive with both eyes open, it is most reasonable to make the standard a binocular one; that is, 20/40 should be obtainable with both eyes open. The driving task remains the same whether the individual is wearing correction or not, so there is no sound basis for having a more lenient standard for the individual with correction. Similarly, there is also no evidence to show that vision in the remaining eye of a monocularly blind individual develops perceptual abilities that compensate for the loss of the eye. Therefore, making the visual acuity requirement more stringent for monocular individuals is not justifiable. Monocular individuals can be identified by visual field screening or, if this type of screening is not used, by measuring visual acuity in each eye. Monocular drivers should receive special instructions and have special mirror requirements.

We consider that it is impossible to establish a single visual acuity standard that would perfectly distinguish between those who should have licenses and those who should not. A single and rigid cutoff point cannot be justified given that there are so many other attributes that contribute to overall safe driving performance. A reasonable approach is to establish a "gray" region. One end of the region will correspond to the criterion for referral (20/40), and the other end to a criterion for automatic denial (this might be an acuity as poor as 20/200). Individuals whose best visual acuity lies in the gray range would be eligible for a special restricted license or for license denial. The stringency of restrictions and denial rates would increase with lower levels of acuity within the gray range. Possible restrictions were listed earlier. It might be expected that individuals in this gray region would be required to take a special test of driving skill, and the tests might be made more extensive for those in the poorer acuity end of the range.

Individuals who at their initial screening do not meet the 20/40 standard should be denied immediate licensure and be referred for an eye examination and proper optical correction. Those who return for reassessment and meet the 20/40 standard would be eligible for licensure.

Application for special restricted licenses would require the applicant's eye doctor to report relevant acuity measurements, refractive data, diagnostic and prognostic opinions, and other relevant findings that could include visual field and night vision evaluations. The applicant could also be required to undergo a driving test by an experienced driver-tester. It would be appropriate for additional costs to be borne by the applicant.

The final decisions regarding licensure and restrictions for gray-zone applicants should be made after the driving test. They involve consultation among

DMV officials, a knowledgeable vision consultant, and the driver-tester who worked with the applicant. Accident and conviction rates of drivers with special restricted licenses should be closely monitored, and the special licenses should be easily revocable by the DMV. More frequent renewals could be considered and new eye examinations and driving tests could be required at each renewal.

Tighter standards or more stringent restrictions, or both, should be considered for drivers of large commercial or passenger vehicles.

Visual Field

The extent of horizontal visual field should be measured with a white object on a dark background. The object should subtend an angle of at least 1 degree. The screening standard should be 70 degrees to either side of fixation. A severe restriction of field (perhaps to a diameter of 20 degrees or less) could be used as a firm criterion for denial. Individuals with field loss between the referral (70 degrees) and denial (20 degrees) criteria should be given special consideration, which could result in denial or special restrictions. Such a procedure would accommodate monocular individuals with one normal eye.

Tighter standards should apply for drivers of large commercial or passenger vehicles.

Bioptic Telescopes

If bioptic telescopes are to be permitted for drivers with reduced acuity, sensible requirements might be that the visual acuity through the telescope at least meet the prevailing visual acuity standard (20/40) and that the binocular acuity (which is relevant when the wearer is not viewing through the telescope) meet a specified standard (this might be in the 20/100 to 20/200 range). In establishing their own standards for binocular acuity without a telescope, DMVs should recognize that individuals whose vision is closer to the extreme limit of the tolerable range are more likely to require special driving tests, to fail driving tests, and to have special conditions imposed on their driver's license. Imposing a tighter standard means that some potentially adequate drivers might be denied the opportunity to demonstrate their driving competence. In contrast, a more lenient standard means that more time will be spent testing drivers who might eventually fail the driving test, and it places more reliance on the driving test as a predictor of the individual's capacity to drive safely.

Bioptic telescopes for driving should be worn in front of one eye only. The other eye should have a specified minimum visual acuity (perhaps 20/200), and the visual field of either eye should meet the driver's license standards.

The bioptic telescope wearer should be skilled at switching between viewing through the telescope and viewing through the carrier lens portion of the device.

The first license issued to a bioptic telescope wearer should require an extensive road test of the applicant's driving abilities. There may be justification for demanding more frequent renewal, more careful monitoring of conviction and accident records, and perhaps more frequent retesting of vision or driving skill. Any restrictions should be decided on individual grounds depending on the causes and the visual consequences as well as a wide range of other personal factors.

Authorities responsible for programs that permit the use of bioptic telescopes may be required to make some difficult judgments. How much poorer than the vision-screening standard should vision be before a bioptic telescope system is recommended or demanded? It is our understanding and experience that most bioptic-wearing drivers have regular visual acuity in the 20/80 to 20/125 range and wear telescopes in the 2.5X to 5X range. Applicants whose vision is closer to meeting the screening standard are less likely to require these devices. A more vexing judgment is how poor visual acuity can be before the individual is considered an unsafe driver, even if a bioptic telescope is used. Many would consider 20/200 or 20/160 to be lenient criteria for this purpose. Were such tolerance permitted with the proviso that the applicant pass an extensive test of driving skills, it could be anticipated that individuals whose vision is at the poorer end of the tolerable range would show higher (perhaps substantially higher) failure rates on the driving test. Clearly it would be prudent for DMVs to carefully monitor the accidents and violations of drivers who are licensed without meeting the vision-screening standard.

Frequency of Screening

We recommend that visual acuity and visual field be screened at the time of license renewal. This is most commonly done every 4 years, which is reasonable. However, an argument could be made for less frequent vision testing (every 8 years) for younger (under 45) drivers.

RESEARCH

Dynamic Visual Acuity

Considerable attention has been given to the possible use of dynamic visual acuity as a visual standard for driving. However, much more research is needed. A standardized test that is relatively quick to administer and gives repeatable measurements is needed. Normalized data on a large population should be developed. Professional eye care for individuals who perform below

normal limits needs to be considered. The effectiveness of treatment on dynamic visual acuity and the improvement in performance of the driving task need to be established.

Night Vision and Glare Sensitivity

The currently used visual acuity and visual field tests do not identify all individuals with night vision difficulties. It is not practical to measure visual acuity at low-light levels during driver licensing because of the time required to adapt to dim light conditions. However, some glare sensitivity measurements could identify those individuals with conditions that cause night driving difficulties. Further study toward developing standardized testing for glare sensitivity could be fruitful.

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