

CHAPTER 401

Driving with Low Vision: Who, Where, When, and Why

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Overview

Regulations regarding the visual requirements for driving are set individually by each state resulting in significant lack of uniformity across states regarding who can drive when and where. This variability is attributable to the lack of reliable information about the level of visual function needed for safe driving. A review of current regulations and the state of knowledge about driving and vision with and without visual aids is provided. Possible explanations for the differing regulations and visual criteria set by various states are discussed.

INTRODUCTION

Driving is a privilege not a right. Yet, especially in the USA where public transportation is often lacking or limited driving is essential. Loss of driving privileges for the elderly leads to social isolation, economic difficulties, and limits access to healthcare and other services.¹ Furthermore, driving cessation has been shown to increase depression amongst the elderly.^{2,3} For younger people loss or inability to gain driving privileges limits job opportunities, social interactions, and may severely restrict location of housing and life style. Thus one would not like to withhold driving privileges unless absolutely necessary. Interpretation of the American with Disabilities Act⁴ prohibits unjustified limiting of a driving license as discrimination against the disabled.

The idea of low vision driving evokes emotional objections from lay people and professionals alike. This response is understandable as almost as many Americans die in car accidents every year (43 200 in 2005)⁵ as were killed in 7 years of the Vietnam War (58 965).⁶ Many people believe that low-vision driving will lead to an increase in these already frightening accident statistics. This belief, however, is not founded on scientific data, and indeed is frequently in direct contradiction to such data. The visual requirements for driving are frequently misunderstood due to reliance on driving regulations that appear to have been arbitrarily established in the face of a dearth of scientific evidence. As a result, the vision requirements for driving regulations vary widely from state to state and also differ significantly from regulations in other countries, most notably with respect to the regulations regarding restricted driving with low vision, with or without visual aids.⁷

Each state (and the District of Columbia) sets its own regulations for vision requirements for driving. This chapter reviews rules in all 51 jurisdictions with particular emphasis on the regulations governing driving with low vision (vision impairment). It highlights variations in vision criteria used to determine those who can drive in various states without restriction (unrestricted license), and the types of restrictions on when and

where the visually impaired (with restricted licenses) may drive. An attempt is also made to account for or explain why specific regulations were developed. The data were taken from questionnaires completed by all 51 jurisdictions. The responses were summarized as state by state tables in a book by Peli and Peli⁸ and updated for changes that have occurred since the book's publication.

RESTRICTED AND UNRESTRICTED DRIVING LICENSES

In all states there is a set of vision requirements (Visual Acuity – VA and Visual Fields – VF) for driving with an unrestricted license. Driving candidates who meet the unrestricted license standards and pass all other tests and requirements may drive anywhere and anytime. The unrestricted license requirement is simply a screening standard and is not intended to represent a prohibition on driving for anyone falling below this level (although it is treated this way in many other countries and in a few states). In most states there are also other regulations that govern the granting of a license to those who fail to meet the unrestricted driving standards. Typically a secondary level of requirements is set which when met can result in a granting of a restricted license. The most common restriction applied is the limiting of driving to daylight hours only. Other restrictions may include specific locations that are permitted or excluded (e.g., highway) for operation of a motor vehicle. Restrictions may be set by law or may be imposed by the registry of motor vehicle based upon the recommendations of an eye care provider or other physicians. Most low-vision driving is therefore by definition carried out under a restricted license.

VISUAL ACUITY (VA) REQUIREMENTS

Most VA requirements for an unrestricted license are specified with refractive correction (or uncorrected, if correction is not needed) in the better eye. In common with many countries around the world, 40 out of the 51 jurisdictions require VA of 20/40 or better for unrestricted driving. There is no known reason for the 20/40 VA requirement as discussed in various published reviews of vision and driving.^{9,10} It is frequently stated that VA of 20/40 enables reading of road signs on the highway in time to respond. However, the size of letters on road signs might be designed to meet the 20/40 VA requirements and not vice versa (although rules for road sign design were interpreted to be dictating letter size requiring VA of ~20/20 for timely response,¹¹ this is not what is practiced). A few states permit VA worse than 20/40 for an unrestricted license, with Florida permitting unrestricted driving with VA as low as 20/70. There are no known reasons for any of these VA standards,

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except that the political power of the large elderly population may be responsible for the lower requirement in Florida. Many states require better VA for an unrestricted license for people with one blind (or 'legally blind') eye than is required for people with two legally 'seeing' eyes (Florida requires 20/40 in the better eye). The reasons for a stricter VA requirement for monocular drivers are not known, but possible reasons are addressed in the discussion.

In most states, a restricted license may be issued to drivers who cannot meet the VA requirements for an unrestricted license. Many of these cases and the restrictions imposed are decided on an individual basis by an advisory board. In some states the restrictions are built into the regulations. In Massachusetts, for example, where 20/40 is required for an unrestricted license, daylight-only driving is permitted with VA of 20/70 or better and driving with a bi-optic telescope during daylight only is permitted if the VA is 20/100 or better in both eyes. Fifty jurisdictions specify a minimum level of VA below which driving is not permitted under any circumstance. These minimum VA levels vary significantly across the states (four states specify a minimum VA of 20/40 and three, a minimum of 20/200). There is no known justification for any of these VA levels. Since Burg's seminal work,^{12,13} numerous studies reviewed by Owsley¹⁰ and Charman⁹ have found no association or only a weak association between VA and crash rate. This is not a result of a lack of low-vision drivers on the road, as many states do not screen for VA at license renewal, many permit mail or online renewals, and many visually impaired drivers continue to drive until they lose their license. The fact is that current research does not provide any clue to the level of VA needed for safe driving,¹⁴⁻¹⁷ forcing the regulators to be creative, resulting in the large variability in VA requirements. Only a few driving-related tasks have been identified by most visually impaired drivers as being difficult due to their limited acuity.¹⁸ These tasks include reading road and street signs, and determining the color of traffic lights. All these tasks may be performed with the aid of a bi-optic telescope.

DRIVING WITH A BI-OPTIC TELESCOPE

Driving with bi-optic telescopes is permitted in 36 out of the 51 jurisdictions. Bi-optic telescopes are miniaturized telescopes mounted in the spectacle lens (usually over one eye only).^{19,20} These are typically mounted at the top of the carrier lens and are used intermittently (Fig. 401.1) to compensate for VA loss (read road signs, examine traffic lights, and scan ahead for

potential road hazards).²¹ Ninety-five percent of the time the driver is viewing through the carrier lens,¹⁸ which provides an unrestricted field of view, but they are viewing without the benefit of magnification. The field of view through the telescope is quite narrow (10–15°) and is surrounded by a ring scotoma.^{20,22} Only a few states restrict the maximum power (magnification) of the telescope (3.0X in Massachusetts), apparently to allow a wider field of view. The field of view through the telescope, however, is not specified (to our knowledge) in the regulations of any state.

The ring scotoma is a result of the magnification itself, and not due to the body of the telescope, as has frequently been stated erroneously in the literature.²³⁻²⁶ The magnified image simply occupies a much larger retinal area than the unmagnified view, thus preventing visibility of surrounding areas and creating a ring scotoma. Of course, a badly designed telescope or mounting hardware could create an additional scotoma (i.e., the upper field scotoma shown in Fonda),²⁷ but this is rare. The potential danger of the ring scotoma obscuring a traffic hazard when driving has been the main objection raised by opponents of bi-optic driving.^{14,28,29} These arguments ignore the facts that telescopes are used very intermittently, and commonly only one telescope is used permitting the fellow eye a continuous view of the environment (in some states the use of a monocular bi-optic telescope is mandated by law).

A number of authors have claimed that the ring scotoma is not present in the binocular view when binocular patients use monocular telescopes.^{20,22,23} These conclusions were based on perimetric studies apparently conducted using subjects with no pathological VF loss. While we confirmed these findings with standard perimetric tests, at least for experienced bi-optics users, we also demonstrated that when patients with central VF loss use monocular bi-optic telescopes they may have a binocular central scotoma³⁰ due to the overlap of the ring scotoma with the disease-related scotoma in the other eye.³¹ It is not known whether, in more complex visual environments, such as those encountered when driving, it will still be possible for the fellow eye to usefully detect potential hazards when the driver is viewing through a monocular telescope.

Other objections to the use of bi-optic telescopes have been raised under the argument that the improvement in acuity is not consistent with the magnification. While this is true when normally sighted observers are tested with bi-optic telescopes (due to optical limitations of some of the devices), low vision patients tested with bi-optic telescopes in our lab were consistently found to gain as much acuity as would be predicted from

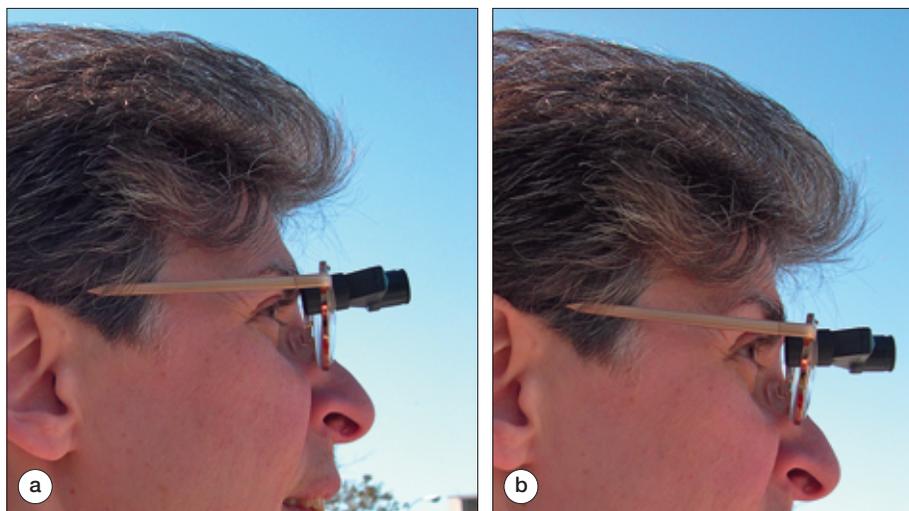


FIGURE 401.1. Bi-optic telescope in use.

(a) Most of the time the user is viewing through the carrier lens not through the telescope. (b) When an object that can not be resolved is seen through the carrier, the user makes a small head tilt forward to bring the telescope in front of the eye and aims it at the object of interest to permit a magnified view such that the object can be resolved. Ocutech 3.0X Mini Keplerian telescope is shown. This small bi-optic provides 12–15° field of view (depending on the distance of the ocular from the eye).

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the magnification. Keeney³² argued that the vibrations of the telescope in the car will reduce the acuity benefit. However, he provided no evidence and apparently based this conclusion on the loss of visibility when a high power celestial telescope is vibrating and on the effect of vibrations of helicopters on visibility through high power (7.0X) binoculars. Keeney further argued that the velocity-induced smear reduces acuity through the bi-optic during driving. His evidence for that, however, was from unreference studies. More importantly, speed-induced smear is high where the retinal image velocity is high (i.e., in the periphery, see Fig. 401.2), thus high speed movement reduces the VF, not the resolution. Due to the small field of the telescope, the optical flow field seen through the telescope involves very low velocities that are unlikely to cause any of these effects.

Regulations regarding the use of bi-optic telescopes vary across the states. While 36 states permit driving with bi-optic telescopes, only two (Connecticut and Oklahoma) explicitly prohibit it. Only 18 states require a special road test with the telescopes and 12 states require special driver training for bi-optic drivers (Michigan recommends such training). The reason for these limited requirements is not known, but it appears that most states impose only requirements that result in little or no cost. Thirteen prohibit driving with a bi-optic at night (Illinois and Maryland prohibit night driving only during the first year of bi-optic licensing). In most of these states an individual waiver can be obtained. Only the state of Oregon does not permit bi-optic night driving under any circumstances. A few states have no specific regulations regarding night driving with a bi-optic, and a few explicitly permit it. Besides the fact that accident rates at night are highly elevated for all drivers, there are no studies showing or suggesting that bi-optic drivers are more impaired at night than they are during the day.

The above discussion typifies much of the handling of driving and low vision in the literature. Conclusions are usually drawn by inference and argued emotionally without the benefit of scientific evidence, either direct or indirect. As a result, the regulations for driving with bi-optics are very variable. In six of the 36 states permitting bi-optic driving, the VA requirement (through the carrier lens) for licensing with a telescope is the

same as without the telescope! These 'empty' permissions are probably a response to interpretation of antidiscrimination federal laws that suggested that one could not prohibit people from driving with bi-optics (see Appendix A in Peli and Peli's book).⁸

SAFETY OF DRIVING WITH A BI-OPTIC TELESCOPE

Studies of the records of bi-optic drivers found them to have slightly higher accident rates than the average of the population. Rates found were 1.2X in California,³³ 1.34X in Texas,²³ 1.2X in Illinois,³⁴ and 2.2X in a more recent California study.³⁵ These higher rates were found to be statistically significant even when corrected for age and gender (bi-optic drivers are younger and include a higher percentage of males than the general driving population). The slightly higher accident rate has been taken by some to mean that bi-optic driving is not safe and should be banned. However, there are many groups with higher accident rates than the average of the population. An accident rate 18X that of the population mean was reported for 16-year-old drivers.³⁴ This is 10 times worse than the highest rate reported for bi-optic drivers. A high percentage of bi-optic drivers obtain their first license with a bi-optic telescope, 59% reported by Bowers et al¹⁸ and 36% by Taylor.³⁴ New drivers are notoriously bad and, though much of their poor record may be attributed to the risk-taking behavior of teenagers, lack of driving experience clearly contributes to their high-accident rate. Thus it is not surprising that some of the studies cited above found a higher rate of accidents for bi-optic drivers.

Other groups also have higher accident rates than the average of the population. These include people with physical impairments, mental impairments, heart disease (even when excluding those having accidents due to a heart attack at the wheel) and hearing impairments. The Blue Mountain Eye Study found the prevalence ratio (PR) of accidents in hearing impaired to be 1.9, similar to the PR for patients with reduced acuity in the same study,³⁶ and higher than the PR of accidents previously reported for bi-optic drivers.

VISUAL FIELD (VF) REQUIREMENTS

Peripheral VF requirements for licensing are specified in only 36 states, ranging from a horizontal binocular VF of 20–150°. The Federal government requirement for commercial interstate drivers is a VF of 70° horizontally in each eye, considerably less than the requirements imposed by many states for professional or private drivers. In most states, the VF requirements are defined in terms of the extent of the binocular VF along the horizontal meridian or simply in the horizontal direction. Only two states, Kentucky and Utah, specify the extent of the VF vertically to include at least 25 and 20° respectively, above and below fixation. The field of view through a common car windshield includes only 15° above and below the center of the windshield. No specific requirements regarding central or paracentral scotoma are specified in any jurisdiction. While the regulations may be interpreted to imply no interruption of the VF along the horizontal meridian, this is clearly not the case. All states permit driving with monocular vision, and in these patients the physiological scotoma (optic disk) interrupts the VF along the horizontal meridian. Bailey and Sheedy¹¹ recommended a screening standard of 70° on each side in the binocular field (total of 140°) for unrestricted license, and a diameter of 20° as a limit for absolute minimal field. They recommended individual evaluation for visual fields anywhere between these two limits.

A histogram of the VF requirements for different states (see fig. 4 in Peli)⁷ shows that the binocular requirements are distributed ~110°, with an additional six states requiring 70°,



FIGURE 401.2. Speed induced smear is illustrated by a photograph by Bruce Dale taken from a speeding car. As this image illustrates the effect of the speed is larger where the optical flow is faster, in the far periphery. In the frontal field where a bi-optic telescope is likely to be aimed there is minimal effect of the speed on the resolution available in the image.

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and nine more states requiring 140°. The reason for the distribution ~110° is not known. The requirement for 70° reflects the Federal requirement for commercial interstate drivers (70° in each eye, although the source of the Federal requirement is not known either). The reason for the peak in the distribution at 140° is probably a result of misinterpreting the Federal requirement for commercial drivers to mean a binocular VF of 140° (the sum of two monocular VFs of 70°). While it may seem unreasonable to make such an error in view of the large overlap of the VFs of the two eyes, such mistakes are found even in the ophthalmic literature dealing with the VF requirements for driving.³⁷

In a few states requirements for the extent of temporal and nasal VF in each eye are specified. The state of Missouri requires 70° binocular VF for both restricted and unrestricted licenses. Restrictions are imposed if the VF of one eye is below 55° (the VF of the other eye then has to be larger than 85°) and may be imposed even if the binocular VF is wider than the minimum 70°. The state of Wisconsin requires at least 20° of temporal VF in each eye. With this requirement, a patient with monocular complete temporal VF loss will be disqualified, even if his binocular VF is sufficiently wide to meet the binocular VF requirement. Despite this regulation, people with monocular vision drive in Wisconsin as they do anywhere else in the world. The reason for monocular VF requirements in the presence of a wide binocular VF is unclear. It may reflect a lack of understanding of basic VFs theory, though it might have been designed specifically to exclude patients with bitemporal hemianopia (however, that could have been done directly and under specific conditions that might justify such exclusion (e.g., measured binocular scotoma)).

Although the required VF is usually defined in terms of the extent of binocular VF along the horizontal meridian, the method of measurement is rarely stated. Measurements may be obtained by careful confrontation (District of Columbia) or by clinical perimetry, although the specific targets are hardly ever specified (e.g., 6 mm target as specified in Michigan, or Goldmann III4e as specified in Kentucky). Most commonly, the VF is evaluated using a single light on each side of the field using one of several available screening devices (e.g., Optec 1000, Keystone View, Stereo Optical DMV 2000). These tests are easy to defeat unless applied with great care and attention, which is rarely the case. In some instances, they might not be applied at all, e.g., if the operator at the DMV vision-testing station notes after hundreds of assessments that the test is not very sensitive and seldom, if ever, provides any information.

The minimum VF requirements for a restricted license are specified in only 12 states.⁷ Only small reductions in the VFs (e.g., 10°) are permitted for restricted licenses in these states. The impact of such small changes in VFs on driving is not known, but is unlikely to be meaningful. In addition to restrictions on where a driver may drive with restricted VFs, a number of jurisdictions require outside mirrors for granting of such licenses. A left outside mirror is required in the State of Washington and the District of Columbia. Outside mirrors on both sides are required in Illinois, Iowa, Maine, Maryland, and Nebraska. Rear view mirrors can only be used to view the area behind the driver, where vision is not afforded even by the widest extent of the VF. Since these mirrors are typically used foveally by both normally sighted and drivers with VF loss, it is not clear why the legislators chose to impose these as a condition for driving with restricted VF. Mirrors mounted in different ways could possibly provide field expansion for drivers with VF loss,³⁸ but such applications are neither required nor permitted in any states.

A reversed (minifying) telescope might expand the VF but reduces VA. Szlyk et al³⁹ evaluated a minifying telescope (the recently discontinued Amorphic lens) as an aid for driving with

peripheral field loss. The telescope was mounted in a lower bi-optic position to 'obtain a full view of the dashboard and peripheral landscape while driving'. The need for a bi-optic minifying device in the lower field is not clear, despite the positive reports from their study. No field expansion device is explicitly permitted in any state. In fact, in a few states the regulations prohibit any such device, either existing or to be invented. This situation is quite different from the widespread recognition of bi-optic telescopes as a device that compensates for reduced VA when driving.

In retrospective and prospective studies,⁴⁰ the Useful Field of View (UFOV) test has been found to be predictive of driving safety assessed in terms of crash rate. Despite its name, the UFOV test is not a VF test. It is a cognitive test assessing a person's speed of information processing and ability to divide attention and ignore distractions. The UFOV test only probes the central 30° of the VF.⁴¹ It is applicable to drivers with totally normal VFs who are free of eye diseases. Thus, although this might be an important test, it is not addressed further in this chapter.

SAFETY OF DRIVING WITH VF LOSS

Intuitively it seems that a wide peripheral VF is needed for safe driving. However, it is not obvious what minimum VF extent would be consistent with safe driving. Danielson⁴² evaluated 680 drivers selected to be at high risk because of VF defects or because of an extensive accident history. He noted: "that no cases were encountered in which the defective field of vision was believed to have caused an accident." Numerous other studies found no correlation between crash rates and VF deficits.^{13,36,43,44} People with severely reduced VF in both eyes were found in one study⁴⁵ to have twice the rate of crashes and traffic violations than people with normal VFs. McGwin et al⁴⁶ found that a diagnosis of glaucoma *per se* is not associated with increased crash risk. More recently McGwin et al⁴⁷ reported that glaucoma patients with moderate or severe loss in the central 24° radius of the VF in the worse functioning eye are at increased risk for involvement in a vehicle crash. Note, however, that moderate and mild loss in the better eye were not associated with increased risk, and while severe loss in the better eye was associated with increased risk of accidents, that effect was not statistically significant. Thus even the impact of severe VF loss on crash risk remains unclear. North⁴⁸ reviewed the literature on VFs and driving and concluded "Until further research work does determine the minimum visual field required for safe driving, the role of the medical practitioner in advising patients when they are considered unsafe to drive is in question." More recent studies have not shed enough light on the issue to change this assessment.

When driving performance is assessed directly rather than by measuring crash rates, a relation between VF extent and performance does emerge. Wood and Troutbeck⁴⁹ found that driving performance of normally sighted drivers was affected when wearing goggles that reduced the VF to 40°. Lovsund et al⁵⁰ assessed target detection in a driving simulator and reported that patients with VF loss performed significantly worse than drivers with normal VFs. The task, however, was essentially just a perimetry test performed in the simulator, and thus does not illuminate the question at hand. We have recently evaluated driving performance of glaucoma patients with mild to moderate VF loss (residual horizontal binocular⁸ VF ranged from 78° to 165°) on a 14 mile course on public roads in Birmingham AL.⁵¹ Even with this moderate VF loss, we found significant correlations between residual VF size and driving performance on various skills and maneuvers for which a wide VF was likely to be important. A strong correlation was also found between

driving habits (in terms of self restricting driving behaviors),⁵² and residual VF extent, indicating that even at this moderate level of VF loss, patients are aware of their limitation and restrict their exposure accordingly. It should be noted, however, that only one of our 28 subjects (with a VF of 109°) was deemed unsafe to drive.⁵¹ However, in another on-road study of drivers with more restricted peripheral VFs (mean 84 ± 35° compared to 123 ± 20° in our study),^{51,53} only 43% passed a test of practical fitness to drive. In a retrospective study of on-road driving assessment records at a rehabilitation center,⁵⁴ the extent of VF loss (of mixed types mostly due to head injury and strokes) did not have a significant impact on driving performance, and the location of the loss was not significantly related to driving fitness.

Our findings⁵¹ of an effect of mild to moderate VF loss are not consistent with results reported by Szlyk et al⁵⁵ for a group with a similar range of peripheral VF loss evaluated on a short driving simulator test (5 min) using general measures of simulator performance. They found no increase in crash rate (on the road) for the patients compared with normally sighted controls, and no difference in simulator performance except that patients had a longer response time to a stop sign. That stop sign appeared at an initial eccentricity of 30° along a curved portion of the road. At that eccentricity it should have been well within the VF of all subjects. In a later study of 40 glaucoma patients with wider range of peripheral field loss and 17 normally sighted control subjects the same group found quite different results.⁵⁶ In the simulator they did not find a difference in response time to the stop signs appearance between patients and controls, but they did find a significant difference in accident rate. Seven accidents occurred for the patients and only one for the controls. It is not clear what simulator situations resulted in accidents during just 8 min of drive. The second study found a higher rate of on-road self reported accidents for the patients and that the visual field loss was significantly correlated with driving performance, in contrast to the earlier study. Coeckelbergh et al⁵³ evaluated 87 subjects with peripheral and central VF loss in a driving simulator and an on-road driving test. They reported that subjects with VF defects (central and peripheral) showed reduced performance on measures of driving speed, steering stability, lateral position, etc. They found that simulator measures increased the predictive power of the analysis regarding fitness to drive, indicating that the predictive power of clinical tests of visual function alone was insufficient. In a study of 100 patients with central and peripheral VF loss,⁵⁷ they reported that a smaller percentage of patients with central VF defects passed the on-road driving test than patients with peripheral or mild VF defects.

Thus, while most recent studies clearly find an effect of VF loss on driving performance, we still do not know the level of loss that is inconsistent with safe driving. It appears also that in driving assessments only patients with moderate to severe peripheral VF loss are found unsafe to drive. Compensatory techniques may help such patients increase their driving safety.⁵³ It is also not clear yet how one can help patients develop such compensations.

Monocular patients (those who lost vision completely in one eye) may be considered to have a modest peripheral VF loss (on one side), and a small mid-peripheral loss due to the physiological scotoma. Monocular patients are permitted to drive in all states and all countries. On-road test results from a rehabilitation center⁵⁴ indicated that a large proportion (79%) of monocular patients were safe drivers and that the side of the deficit had no significant impact. Patients are rarely admitted to a rehabilitation center for monocular loss of vision, so those patients likely had additional impairments. While Federal regulations prohibit people with monocular vision from driving

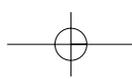
interstate trucks, in a number of states they can drive trucks locally. A study that compared binocular and monocular truck drivers found the monocular drivers to be deficient on various visual functions but concluded that 'monocular drivers are not significantly worse than binocular drivers in the safety of most day-to-day driving functions'.⁵⁸ Bailey and Sheedy¹¹ in addressing driving standards stated that the few studies that found monocular drivers to be more dangerous had 'substantial design or reporting limitations, or both'. Bailey and Sheedy also recommended that monocular driver be educated about their limitation and have an out side rearview mirror mounted on the side of their visual field deficiency, but did not explain how the mirror would be helpful.

DRIVING WITH HEMIANOPIA

Most driving regulations implicitly treat hemianopic VF loss in the same manner as any other restriction of the peripheral VF. Thus, the VF requirement refers only to the total horizontal extent of the field. Patients with hemianopia measured with standard clinical procedures frequently have a horizontal VF of 90°, and thus fail to qualify in 22 states. In fact, the temporal VF may extend more than 90°, although a modified test procedure is required to document such a VF with most clinical perimeters.⁴² Thus, some individuals with hemianopia might even meet a VF requirement of 110°. One state (Utah) requires that drivers with hemianopia be evaluated individually for driving qualification. Driving with hemianopia is permitted following a special road test in the Netherlands and in Belgium, but it is explicitly prohibited in the UK. Because many states do not prohibit driving with hemianopia and because many patients can easily pass the VA screening, many of them are driving but their driving records are unknown. Tant and colleagues,^{59,60} tested on-the-road driving of 28 patients with hemianopia, including those with neglect and other co-morbidities. Four of this mixed group were found to be safe and qualified to drive by the state driving testing authority. Following training, two more out of 17 who failed the first test were also qualified to drive.⁶⁰ Thus, even without pre-selection, 20% of patients with hemianopia may be able to drive safely.

Schulte et al⁶¹ compared driving performance of nine hemianopes with 10 controls in a realistic driving simulator. They found no differences in any of the tested parameters (driving speed, reaction time, and driving error rate) between the visually impaired subjects and the normal participants. They concluded that patients who have hemianopic VF defects should not summarily be denied a driving license. A study that compared the on-road assessment results of 13 hemianopes and seven quadranopes reported that hemianopia tended to have a worse impact on driving performance than quadranopia, but the effect only approached statistical significance.⁶²

In a pilot study, we found that hemianopic and quadranopic patients could drive reasonably well in a simulator but they detected significantly fewer of the pedestrian figures that appeared on the side of their VF loss than on the unaffected side.⁶³ Even for pedestrians that appeared at an initial eccentricity of 4°, representing a person on the nearest sidewalk or in the next lane of traffic, the detection rate was significantly lower on the affected side, and for pedestrians that were detected, the reaction times were longer than on the unaffected side. Szlyk et al⁶⁴ conducted a 5 min driving session (following a 15 min practice session) in their simulator and compared six patients with hemianopia (or quadranopia) with and without neglect to age matched and younger control groups. With only six subjects, they attempted to analyze for the effects of age and hemianopia. The patients were found to make more lane border crossings and have greater variability of lane position than the control



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groups. However, motor control of steering in a simulator is quite different from that in a real car, so the deficits in steering control might have been related to difficulties with motor control of the simulator rather than a result of the VF loss. This study was too small and the results too variable to provide any information which can be generalized regarding driving ability of patients with hemianopia.

Mirrors mounted on the car,³⁸ or on the glasses,^{65,66} have been proposed as vision aids for patients with hemianopia. However, no testing of these devices in driving was ever reported. A number of low-vision practitioners promote the use of monocular or binocular sector prisms as an aid for driving with hemianopia.²⁵ However, there are no state regulations that formally recognize prism devices as driving aids for hemianopia and there are no published studies that have shown a benefit of these prism designs when driving. Szlyk et al⁶⁷ reported on fitting 10 hemianopic patients with the round monocular sector prism design of Gottlieb in either a press-on Fresnel (20Δ) or a laminated ophthalmic lens (18.5Δ). They reported modest improvement (13–36% of tasks improved, as assessed by rehabilitation specialists) in a number of visual skills following the prism fitting and training. However, only limited details on the measurements and scoring used were provided, and the percentage of tasks for which performance decreased is unknown (decrements in performance were coded as 'no change'). They found no difference between the Fresnel and the ophthalmic lens designs and reported that two of the patients were permitted to drive legally with the prisms after the end of the study.

Peli⁶⁸ proposed a novel design of peripheral prism correction with the prism applied across the whole lens on the side of the VF loss but restricted to areas above and below the iris (Fig. 401.3a). These peripheral prisms have been shown to expand the VF by ~20° (with 40Δ Fresnel prisms) above and below the line of sight, using standard perimetry (Fig 401-3b). Such VF expansion can not be demonstrated with either the monocular or binocular sector designs. The value of the peripheral prisms for driving has not been proven yet in a study. In 2001, the state of Massachusetts granted a driving license to a hemianopic patient using the peripheral prisms. This patient has now been driving safely for 5 years. Two more patients were licensed with these prisms in Arizona, two in Montreal, Canada, and recently a patient was licensed with these prisms in the District of Columbia. In all these cases the patients met the VF requirements with the prism and demonstrated their ability to drive safely with these prisms during extended road tests. A recent modification of the peripheral prism design (oblique design),⁶⁹ expands the area of expansion to the center of the VF (the area visible through the windshield) without impeding the central single binocular vision. This oblique design is currently being evaluated in an on-road driving study in Belgium.

DISCUSSION

The variability of regulations regarding visual requirements for driving licensure is not consistent either with public safety or with fair treatment of impaired or disabled citizens. As a result of the variability of regulations, people with widely varying types and levels of vision impairments are permitted to drive with varying types and levels of restrictions across the country. With a license from one state, a person can legally drive in another state, despite failing to meet the vision requirements for licensure in that state. The wide variability in vision requirements for driving found between the states is an indication of the lack of consensus in both the scientific and the driver licensing communities about the extent of VF and level of VA that is needed for safe driving.^{9,10,48} Faced with such a lack of consensus and reliable data, regulators with guidance from local ophthalmic practitioners are apparently forced to make arbitrary decisions. It is of interest to speculate how such decisions are formulated. Regulators frequently look to neighboring states for guidance. Such regional tendencies are clearly notable in maps showing driving regulations across the USA (see figures 2 and 3 in Peli).⁷ While this may not be an optimal way to guide public safety, it may be a politically safe approach.

A few jurisdictions have VA-dependent VF requirements. For example in Maryland a VF of 140° is needed for an unrestricted license. However, a VF of 110° is sufficient for a restricted license, but only if the VA is better than 20/70. In the District of Columbia, a VF of 130° is required if VA is better than 20/40. However, if the VA is only better than 20/70, a VF of 140° is required. The rationale for such VA-dependent VF requirements is unclear. Reduction in VA usually results from loss of central vision. Can such a loss be compensated for by an increase in the required VF? It is possible that these kinds of cross requirements are derived from the computations of vision efficiency or vision disabilities used for insurance, social security, or legal compensation for vision loss. In many of these situations the visual 'disability' (activity limitation) is computed using a linear weighting formula such as

$$\text{Disability} = K \cdot (\text{visual acuity score}) + C \cdot (\text{field score})$$

where, K and C are the weighting coefficients. Such formulation implies that an improvement in the VF may compensate for a loss of VA and vice versa. Fishman et al³⁷ study that compared driving records with various measures of visual efficiency in patients with RP explicitly implemented such a linear weighting formulation to determine visual efficiency. While such formulations might be reasonable for various social or medico-legal applications, they do not mean that one of these functions could compensate for a loss in the other for the purpose of driving.

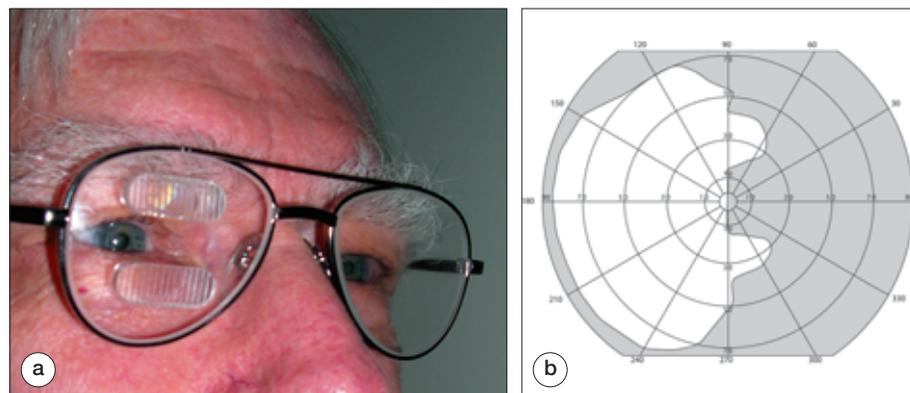
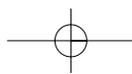


FIGURE 401.3. Peripheral prisms field expansion device for a patient with right hemianopia. **(a)** The permanent embedded PMMA hard Fresnel prisms of 40 prism diopters base right shown in the normal fitting position. Lens shown is the Horizontal EP lens by Chadwick Optical. **(b)** Binocular visual field of a patient with complete right homonymous hemianopia measured with the peripheral prisms on a Goldmann perimeter using the V4e target.



Driving with Low Vision: Who, When, When, and Why

There is no evidence to support such accounting in driving (or for that matter in any other ability), and therefore, they have no place in licensing regulations. All states permit people with one blind eye to drive. However, many require the remaining eye to satisfy a higher standard on VA tests than that required from people with two functioning eyes. The basis for that cross-linked requirement is not known and not justified¹¹, but is likely to be related to the reasoning associated with the VF and VA cross-linked requirements discussed above.

How unsafe is driving with low vision? This seems to be the question that one needs to answer in making decisions about regulations and individual permissions for driving. There is little doubt that drivers with low vision are less safe than drivers with perfect vision. However, as this chapter and many prior reviews have found, the results of research to date do not permit evidence-based decisions to be applied in the public or private domain. As shown with respect to bi-optic driving, many populations and sub-populations have more accidents than the average driver. However, it is unreasonable and impractical to remove all of these people, even if we could identify them. About half of the population has a higher accident rate than the average of the population. If we decide to remove all of them, there will still be half of the remaining population with more accidents than the new average. Thus performance above or below the average is not a reasonable justification to exclude any group. Furthermore, the number of bi-optic drivers remains quite low, so their impact on the total number of accidents is exceedingly small (see ahead). Other simple measures applied to the total driving population, which are not being legislated or enforced (e.g., speed limits), could save orders of magnitude more lives and injuries⁷⁰ than could be saved by banning bi-optic driving or any other low-vision driving.

The level of variability in regulations across states should serve as an ideal test environment for assessing the impact of various vision impairments and restrictions on safe driving. However, there is little data available on the impact of the variable regulations. Unfortunately, most states do not collect any statistics on their visually impaired drivers and the level of enforcement of existing regulations is variable even within states. California

does maintain such records and a study conducted in the early 1980s provides some insight.³³ At the time, there were only 229 bi-optic drivers out of 21 million drivers in California. Biopic drivers had a higher rate of accidents and injurious accidents than the total population. However, when the computations were corrected to account for age and gender differences, and excluded drivers with invalid licenses from both groups, the difference was not statistically significant. It is also important to consider the absolute numbers not just the rates. The bi-optic drivers in that study apparently added a total of three accidents to the rate of 1.1 million accidents per year. It is impossible to make policy decisions based on such data. The driving records of patients with vision impairments from those states that permit low vision driving should be collected and compared to matching populations in the other states. The data to be generated from such studies should provide a more solid basis for the determination of the vision requirements for safe driving and the possible role of vision aids for driving with impaired vision. With better data and analysis, the variability in licensing requirements between states could be reduced, thus improving safety and the fair treatment of visually impaired drivers.

Many elderly drivers with modest visual loss due to cataract,⁵² with moderate VA loss due to AMD⁷¹ or with moderate VF loss due to glaucoma⁵¹ self-limit their driving. They drive to fewer places, shorter distances and in less dangerous environmental conditions, limiting their exposure and reducing the risk to themselves and to others. Similar restriction could be imposed by the registry at recommendation of an eye doctor. Such limitations may keep many patients from total isolation and lack of services while posing no significant loss of public safety. This approach seems most appropriate until a better body of knowledge is developed to permit clearer identification of those visually impaired patients who should not be driving.

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