Introduction: Driving is recognized to be a visually intensive task and accordingly there is a legal minimum standard of vision required for all motorists. The purpose of this paper is to review the current United Kingdom (UK) visual requirements for driving and discuss the evidence base behind these legal rules. The role of newer, alternative tests of visual function that may be better indicators of driving safety will also be considered. Finally, the implications of ageing on driving ability are discussed.

Sources of data: A search of Medline and PubMed databases was performed using the following keywords: driving, vision, visual function, fitness to drive and ageing. In addition, papers from the Department of Transport website and UK Royal College of Ophthalmologists guidelines were studied.

Areas of agreement, areas of controversy, growing points, areas timely for developing research: Current UK visual standards for driving are based upon historical concepts, but recent advances in technology have brought about more sophisticated methods for assessing the status of the binocular visual field and examining visual attention. These tests appear to be better predictors of driving performance. Further work is required to establish whether these newer tests should be incorporated in the current UK visual standards when examining an individual's fitness to drive.

Keywords: driving/vision/review

Introduction

Driving is recognized to be a visually intensive task and accordingly, there is a legal minimum standard of vision required for all motorists. For most people in today’s society, the entitlement to drive is essential for the maintenance of independence and mobility. Therefore, one would expect the visual standards upon which denial of licensure are based to rest upon sound scientific evidence.

The role of vision in driving has traditionally been assessed by observing the association between visual function and driving safety,
usually determined by the number of traffic violations (e.g. failure to obey traffic signs) or involvement in motor vehicle collisions (MVCs). The purpose of this paper is to review the current United Kingdom (UK) visual requirements for driving and discuss the evidence base behind these legal rules. The role of newer, alternative tests of visual function that may be better indicators of driving safety will also be considered. Finally, the implications of ageing on driving ability will be discussed.

The legal visual standards required to drive

The UK Driver and Vehicle Licensing Agency (DVLA) requires differing visual standards from different groups of drivers. Those who drive cars and other light vehicles are classed as ‘Group 1’ drivers, while those driving large good vehicles and passenger carrying vehicles, previously grouped together as HGVs (heavy good vehicles) and PSVs (public service vehicles), are classed as ‘Group 2’ drivers.

Group 1 drivers need to be able to read a standard car number plate, with characters of 79 mm in height and 57 mm in width, with both eyes open at a distance of 20.5 m in good light with visual correction if needed. With the introduction of the new narrower number plate font in 2001, characters of 79 mm in height and 50 mm in width need to be able to be read at a distance of 20 m. This visual requirement is statutory in law. However, it must be stressed that there is no Snellen equivalent of the number plate test.\(^1\)

Group 2 drivers are subject to more stringent monocular visual acuity standards. Since 1997, Group 2 drivers are required to have an uncorrected visual acuity of at least 3/60 in each eye and, with refractive correction, at least 6/9 in their better eye and 6/12 in their worse eye.\(^2\)

In addition to these basic acuity requirements, both groups of driver should have a binocular horizontal visual field of at least 120° assessed using a Goldmann III4e target or similar and have no significant defect, defined using automated perimetry essentially as a cluster of four or more adjacent points missed (full definition available from the DVLA\(^1\)), within 20° of fixation.\(^2,3\)

Failure to achieve the visual acuity or visual field standards required is considered a disability about which both groups of drivers are required to notify the DVLA. In the absence of further evidence such a notification would ordinarily lead to that person losing their entitlement to continue driving, although there are several notable exceptions to this rule.

Group 1 drivers who have previously held a full licence which was lost because they failed to meet the visual field standard are entitled to
apply to have their licence reinstated if it can be shown that the visual field defect had been present for at least 12 months and was caused by an isolated, non-progressive condition.2

Group 2 drivers who fail to satisfy the visual field standard may still be allowed to continue driving provided that they provide the DVLA with a certificate of recent driving experience and have not been involved in an MVC in the 10 years immediately preceding the application in which defective eyesight was considered to be a contributory factor. These ‘grandfather rights’ are defined in the 1996 Motor Vehicles (driving licences) Regulations Section 1968 and apply only to driver visual acuity, and not extent of visual field.

Although the DVLA has the responsibility of determining an individual’s fitness to drive, the onus rests with each individual driver to inform the DVLA if they have a medical condition that may affect their driving ability, or if they have been advised that they may not meet the legal visual standards required. In cases where such a disclosure is not made the UK Royal College of Ophthalmologists advises its members that action may be taken to inform the DVLA directly with the knowledge, but not necessarily permission, of the patient, but that ‘ophthalmologists should only breach confidentiality in good faith where the patient’s vision is likely to make them a danger to themselves or others if they drive’.3

It is worth noting that while passing the ‘number plate test’ is a statutory law requirement, the visual field standard is a requirement for the driving licence.

Visual acuity and driving: the evidence base

Although there is no Snellen equivalent to the ‘number plate test’, many clinicians assume it to be equivalent to a Snellen visual acuity of 6/10 and this assumption is routinely extended in clinical practice to predict that patients with a binocular acuity of 6/9 will meet the standards for Group 1 driving, while patients with a binocular acuity of 6/12 will not. In a study assessing this hypothesis, Currie and co-workers4 tested the ability of 100 ophthalmic patients, half of whom had a binocular acuity of 6/9 and half of whom had a binocular acuity of 6/12. They found that 74% of patients with 6/9 binocular acuity were able to read a standard number plate at the required distance compared with 34% of patients with 6/12 binocular acuity. Although these results broadly validated clinical practice, the level of accuracy provided by Snellen acuity is clearly inadequate for use in such a sensitive and important task. The unreliability of Snellen acuity measurements in predicting the outcome of the ‘number plate test’ is also
recognized by the Royal College of Ophthalmologists who have made it clear to doctors that ‘visual acuity measurements in the consulting room may not correspond to the ability to read a standard number plate...due to differing conditions of glare and contrast’.3

More recent studies have shown that drivers with a binocular visual acuity of 6/12 or worse are not at any greater risk of having an MVC5,6 and that visual acuity at any level is a poor predictor of the risk of MVC.7,8 At the other extreme, patients with severely impaired central vision are still able to recognize and react to commonly encountered road signs while driving at a moderate speed (40 mph).9

**Visual field and driving: the evidence base**

The earliest studies looking at visual field impairment and MVCs reported no association between the two; however, the usefulness of these studies and the conclusions that can be drawn from them are limited by the relatively crude methods of visual field assessment that were available to investigators in the 1970s.10,11

The advent of automated perimetry, and the improved accuracy and reliability that this has provided, enabled investigators to confirm the association between visual field impairment and the risk of MVC. Johnson and Keltner12 compared the accident rates of 10 000 Californian drivers with monocular or binocular visual field loss with age-matched drivers with normal, full visual fields. Drivers with monocular visual field loss experienced similar rates of accidents and driving convictions to those with normal visual fields. By comparison, those drivers with bilateral visual field loss had twice the rate of accidents and convictions. The authors concluded that this was a clear indication of the importance of the visual field in driving performance. This finding was confirmed in a study by Owsley et al.13 which found that the risk of having an injurious MVC was more than doubled in drivers with a visual field impairment (central 30° impairment: odds ratio 2.6, 95% confidence interval 1.1–6.3; peripheral 30–60° impairment: odds ratio 2.4, 95% confidence interval 1.3–4.5).

Studies using driving simulators have also demonstrated an association between driving performance and visual field impairment. In a study comparing the driving performance of 40 glaucoma patients with peripheral visual field loss with that of 17 controls with similar previous driving experience, a strong correlation between the horizontal extent of visual field and the number of virtual MVCs experienced on a driving simulator was found. Patients with a visual field reduction to <100° horizontally were at greater risk of accidents.14
These studies suggest that the loss of visual field is an important and valid predictor for determining driving safety and the likelihood of involvement in MVCs.

Other methods of assessing fields

In the UK, the visual field requirements for driving are usually assessed by means of the Esterman programme on an automated perimeter. The Esterman test was originally devised for manual kinetic perimetry and assesses the binocular visual field. The test generates an overall score that is weighted towards visual ability in the central and inferior field, areas thought to be of greater importance for personal mobility. In the automated, static perimeter, the test programme examines 120 points spread over an area extending approximately $\pm 75^\circ$ horizontally, $35^\circ$ superiorly and $55^\circ$ inferiorly. Each location is tested with a white light stimulus equivalent in size to Goldmann III at an intensity of 10 decibels. Points missed are retested once; two negative responses are recorded as a defect.

The test programme does not quantify the sensitivity values at points across the visual field, instead yielding a crude ‘seen’/’not seen’ outcome. In addition, as the test is binocular, fixation cannot be monitored during the Esterman test. In recognition of this, the Royal College of Ophthalmologists state that ‘a perimetrist should be present with the patient at all times during the test and should carefully explain the test to the patient prior to beginning’ which may be of some help but this is also a standard practice for monocular perimetry in which fixation losses are still seen to occur. In practice, this simply serves to emphasize the inherent differences between the Esterman test and the monocular visual field tests upon which the evidence for impaired driving ability is based. Finally, case selection is an issue; the Esterman test is most often carried out at the request of the DVLA following a driver declaration of a pathology that may affect the visual field.

An alternative to the Esterman test for assessing the binocular visual field is the integrated visual field (IVF) of the PROGRESSOR software (Moorfields Eye Hospital, London, UK/Medisoft Ltd., Leeds, UK) applied to monocular visual field data from the Humphrey Field Analyser (Carl Zeiss Meditec, Dublin, CA). This software can integrate data from each monocular field to produce a simulated binocular visual field in which patients’ best point-by-point sensitivity is displayed. There is a strong agreement between these simulated binocular visual field results and those of the Esterman test in classifying glaucomatous patients with central binocular defects. The advantages of using this software as evidence of patients’ binocular visual field status
are that it provides information on the sensitivity value of each point of the visual field, is controlled for fixation which can be checked during monocular testing, and it utilizes data which is already collected routinely during glaucoma clinics avoiding the need for additional testing to be carried out. Evidence suggests that the IVF may be a superior test of fitness to drive compared with the Esterman test. 17–19

Other tests of visual function: the evidence base

Contrast sensitivity

Visual acuity only describes a patient’s ability to resolve high-contrast detail and tells us little about their ability to detect the larger, low-contrast objects that are encountered in everyday life. Studies of patients with cataracts have shown that contrast sensitivity (CS) may be significantly reduced with only a modest accompanying reduction in visual acuity and yet no attempt is made to measure the CS function within the current DVLA standards. 20,21

Several authors have confirmed the association between CS and driving ability. Rubin and co-workers22 assessed the relationship between visual impairment, including CS, and functional ability in a sample of elderly American volunteers and found that impaired CS was the factor most strongly associated with self-reported difficulty in day and night driving. Owsley and co-workers7 analysed the state recorded MVC data of older drivers and found that drivers with a monocular reduction of CS were three times more likely to be involved in an at-fault crash. This figure increased to a 6-fold greater risk in drivers with binocular impairment of CS. However, other studies have failed to demonstrate an association between impaired CS and MVC involvement.8

Driving at night

Most people drive considerably fewer miles during the hours of darkness. Despite this, more than half of MVC fatalities occur after dark.23 This finding may be explained in part by changes in driver behaviour associated with nightfall, such as increased alcohol consumption, increased driver fatigue and increased driving speeds due to lower traffic density. However, a number of authors have found an association between reduced illumination and driver performance that may contribute to reduced driving safety.

In low illumination, physiological changes occur within the visual system resulting in degradation of both spatial and temporal resolution,
a reduction in CS and poorer colour discrimination. These changes are somewhat moderated during night driving by the presence of headlights, street lighting and reflective road markings, but visual processing still remains impaired compared with daytime illumination.\textsuperscript{24} Drivers are generally unaware of the visual limitations of driving at night as this extrinsic lighting permits them to continue to see road signs and steer their vehicles effectively.\textsuperscript{25} However, they will have more difficulty in detecting the low contrast and poorly illuminated objects commonly encountered at night, and as such exhibit longer reaction times, resulting in longer stopping distances.\textsuperscript{23,26}

The visual standards for licensure are based solely on performance in photopic conditions, although photopic visual acuity has been shown to be a poor predictor of the ability to recognize road signs at night.\textsuperscript{27} Studies have also shown that the disparity between daytime and nighttime visual acuity levels increases with advancing age, with daytime levels becoming increasingly worse predictors of vision at night.\textsuperscript{28} Only in Germany is low-contrast acuity tested in mesopic conditions, in the presence and absence of glare, prior to private or commercial driver licensing.

**Useful field of view**

Driving requires the ability to detect and process visual information from both the peripheral and central visual fields at the same time. Current tests used to assess visual standards are useful in the detection of ocular abnormalities, but they do not fully assess the complex visual abilities required for the task of driving.

The ‘functional’ field of vision describes the ability of an individual to simultaneously process central and peripheral visual information, and is quite different from the map of visual sensitivity determined by traditional perimetric methods. It has been demonstrated that as the quantity of information within the peripheral or foveal field increases, there is a reduction in the extent of the functional field.\textsuperscript{29}

The useful field of view (UFOV) test developed by Ball and co-workers\textsuperscript{30} attempts to quantify the span of attention within the visual field. The commercially available UFOV Visual Attention Analyser (Visual Resources, Inc., Bowling Green, KY, USA) consists of three tests in which the individual must detect, localize and identify suprathreshold targets. Scores from each subtest are totalled to generate a final UFOV, expressed as a percentage reduction from 0 to 90%. It has been shown that a reduction in the UFOV is strongly associated with an increased risk of MVC involvement,\textsuperscript{8,31} and poorer on-road driving performance.\textsuperscript{32}
Visual function in the older driver

As with most Western countries, the UK has an increasing elderly population. In 2003, there were 20 million individuals over the age of 50 years and this number is predicted to increase by over a third by 2031. The improved lifestyle expectations of those in this age group have resulted in an increase in the number of older people who drive and expect to continue driving. It is known that with increasing age there is a decline in sensory, cognitive and motor function and, although many older drivers’ self-impose restrictions on their driving behaviour, older drivers have more accidents per mile driven than their younger counterparts. Furthermore, if an older driver is involved in an MVC it is more likely to be fatal. Better understanding of how functional changes with advancing age affect driving ability is likely to improve safety and quality of life, either from the development of driver education programmes for older individuals or by the introduction of changes in the licensure legislation for visual standards required in this age group.

Sensory function changes with age

After the age of 50, there is a rapid decline in sensory vision, resulting in a reduction of visual acuity, CS, stereoacuity and visual field sensitivity. There have been a number of driving studies to assess the impact of this natural visual decline on driving ability and a more detailed review can be found in the Department of Transport online document, ‘Older drivers: a literature review No. 25’. This decline in sensory discrimination has its greatest impact during night driving, with road-sign legibility becoming increasingly difficult in low illumination levels. At night, older drivers need to be closer to road signs, and view them for longer, before they are recognized.

Age-related pathology and sensory function

Advancing age brings an increase in the prevalence of the age-related ocular pathologies that affect sensory functioning. Cataracts are a common cause of visual impairment in the elderly and their incidence increases with advancing age. Cataracts reduce visual acuity and CS and cause an increase in disability glare, and self-reported difficulties with the tasks of daily living. Older drivers with cataract, even if present in only one eye, are at a greater risk of...
MVC involvement compared with age-matched drivers with no cataract, and this has been attributed to an impairment in CS function caused by the lens opacity.\textsuperscript{7} Removal of cataracts is associated with a marked improvement in both health-related quality of life and in driving performance.\textsuperscript{41,42}

Macular degeneration is the leading cause of irreversible blindness in the Western world and, like cataracts, has an increasing prevalence with age.\textsuperscript{43} Age-related macular degeneration (ARMD) rarely leads to complete blindness as peripheral vision remains unaffected. Early non-exudative ARMD patients report slightly blurred central vision and mild colour disturbances, whereas patients with exudative ARMD more often present with acute, marked loss or distortion of central vision. In a study by Szlyk and co-workers\textsuperscript{44}, the driving performance of patients with ARMD was compared with normally sighted age and driving-experience matched controls, using both a driving simulator and ‘on-road’ assessment. Visual acuity in the ARMD group ranged from 6/9 to 6/60, with a mean acuity of 6/20. Driving performance was markedly worse in the ARMD group, with patients having a greater number of simulator accidents and poorer performance on the on-road driving test, attributable to their poor visual acuity and reduced CS. To our knowledge, there have been no studies assessing driving performance in ARMD patients with visual acuity levels that fall within the UK driving standards.

Glaucoma is the leading cause of irreversible blindness in the world,\textsuperscript{45} affecting 1\% of over 40 years old and 5\% of 65 years old, increasing in prevalence with advancing age.\textsuperscript{46} It is a progressive optic neuropathy that results in a characteristic deterioration of visual function. Early in the disease this manifests as impaired mid-peripheral visual field which progresses if the disease is left untreated. It has been reported that patients with relatively minor binocular visual field loss have a moderate to severe mobility restriction.\textsuperscript{47}

There have been a number of studies assessing driving safety in patients with glaucoma. McGwin\textsuperscript{48} published the results of a retrospective cohort study that evaluated the relationship between glaucoma and risk of MVC involvement. The study looked at police records to ascertain the number of MVCs reported over a 5-year period and found that older drivers with glaucoma were up to 50\% less likely to be involved in MVC. In stark contrast, a study by Haymes\textsuperscript{49} found that people with glaucoma were six times more likely to have been involved in an (self-reported) MVC in the previous 5 years compared with normal control drivers, adjusted for number of miles driven per week, age and gender. It was found that the clinical parameter most associated with MVC involvement was impaired ‘selective attention’ as assessed with the UFOV. The conflicting findings between both studies may be explained by differences in the cohort studied. It is possible that patients studied...
by McGwin and co-workers may have had early disease with minimal impairment of visual function, but as clinical data was not collected for the study this cannot be verified. The results may also reflect the effects of self-regulation among drivers with known glaucoma in this cohort. It is known that individuals with a perceived visual impairment reduce their exposure to ‘difficult’ driving situations, such as those encountered in poor weather or heavy traffic. Adopting such strategies successfully reduces the risk of MVC involvement.

Diabetic retinopathy (DR) is a complication of both type I and type II diabetes that poses a serious threat to vision. DR was the third most common cause of both blind and partially sighted registration in the over 65 years age group in England and Wales in the year 2000. Visual impairment from diabetic eye disease can be caused by macular oedema, sub-clinical microangiopathy, iatrogenic pan-retinal laser photocoagulation (PRP) in the proliferative stages of the disease or by retinal detachment as a late complication. Mathematical modelling has suggested that it might be possible to tailor the pattern of therapeutic PRP burns to avoid damaging the ‘driving’ visual field; however, this has not yet been proven by clinical studies.

Conclusions

Much work has been done to assess the impact of visual abilities on driving performance. From the evidence presented, it appears unlikely that simple cutoffs based on visual acuity and visual field are enough to predict driver safety. Furthermore, drivers with perceived visual impairment will limit their exposure to driving. This behavioural change will lead to an underestimation of the effect of visual impairment on the rate of MVC. The visual standards for driving are continually being reviewed and as yet there is no evidence to support the use of more modern and sophisticated tests of functional ability. There is still a need to clarify the relationship between vision and fitness to drive for the benefit of all those who wish to use our roads safely.

References