New standards for the visual functions of drivers

Report of the Eyesight Working Group

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The Eyesight Working Group

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This document reflects the consensus of experts who gathered to discuss the difficult issues contained herein. Consensus is generally defined as the majority opinion or general agreement of the group. In that vein, it should be noted that consensus does not mean that all of the participants unanimously agreed on all of the findings and recommendations. This report is based on publicly available data and information. The report reflects the views of a panel of thoughtful people who understand the issues before them and who carefully discussed the available data on the issues.

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Summary

This report comprises the advice of the Eyesight Working Group to the European Driving Licence Committee for a possible revision of the standards on vision for driving. On many issues, scientific evidence is scarce, so that continued research remains very important in order to strengthen the basis for the standards. The major recommendations are the following.

1. Visual acuity requirements should be formulated binocularly. For the worst eye of Group 2 drivers, only a minimal standard of visual acuity is required.
2. The paragraph on visual fields should be reformulated to include requirements on the vertical extension, absence of central defects and use of the test method.
3. Requirements for twilight vision should be considered, future introduction of these and other requirements should be made possible and anticipated.
4. Requirements for the absence of diplopia should be formulated, to include Group 1 drivers.
5. An adaptation period should be required after a newly developed eye disease.
6. Restricted licences should be considered for Group 1 drivers. The conditions for such restricted licences should be carefully judged.
7. Regarding periodic screening: current evidence for the efficacy and efficiency of screening is rather scarce. We recommend additional research to be performed in this field. If, due to desired harmonization of European standards, screening should be implemented, we recommend screening (at least for Group 1) should not commence before the age of 60. People with eye diseases / impaired visual functions should be required to verify themselves whether they meet the standards.

Background

Driving is a complex task, involving both perceptual functions and motor skills. Vision is the most important source of perceptual information for the driver (Rockwell, 1972). Because of the potentially significant consequences of impaired driving (damage and injury to oneself and others) it is reasonable to specify standards for the visual capacity of drivers. Strict standards would best serve traffic safety. However, in our society, being able to drive is of utmost importance for many reasons, socially as well as economically. Therefore, standards on vision should be not so strict that subjects are excluded from driving without good cause. Carefully balancing the requirements on vision so that both traffic safety in general and the mobility of individual drivers are optimally safeguarded, remains a continuing challenge to both scientists and government officials.

In 1992, the European Commission established standards for testing the visual function of drivers in the Council Directive 91/439/EEC (1991). In 2003 there was a proposal for a small revision of these standards. Today, a need for wider revision of the standards is recognised in order to resolve some apparent inconsistencies and to make sure that the standards, where possible, are based on scientific evidence. The Eyesight Working Group was established in March of 2004 by the EC Driving Licence Committee to give advice as to how to adjust the standards. This report is the product of the Working Group.
When exposure is taken into account, i.e. when the number of accidents is measured per number of kilometres driven, then there is an increase in the number of accidents with

age (Massie et al., 1997; Ryan, Legge and Rosmann, 1998; Dellinger, Langlois and Li, 2002; Williams and Carsten, 1989), although this has been disputed by others (Stutts and Martell, 1992). Vision may play an important role in this increase in accidents at higher ages. Drivers with ocular disease drive less safely than those without ocular disease (e.g. Wood and Mallon, 2001; Wood 2002). This is also true for specific ocular diseases such as cataract (Owsley et al., 1999; 2002) and glaucoma (Owsley et al., 1998b), although again, this relationship has been disputed by others (Gresset and Meyer, 1994; Fonda, 1989). Cataract surgery has a profound positive effect on self-estimated problems during driving (Mönestam and Wachtmeister, 1997).

As age increases, the prevalence of eye disease increases (Gibson et al., 1985; vanNewkirk et al., 2001; Ivers et al., 2000). This is true for the major eye diseases such as cataract (e.g. Hirverlä et al., 1995), glaucoma (Wensor et al., 1998; Klein et al., 1992; Coffey et al., 1993; Dielemans et al., 1994) and age-related macular degeneration (Vinding et al., 1990; Pauleikhoff et al., 1992). Even in the absence of ocular disease, visual function deteriorates with age (Haegerstrom-Portnoy, 1999; Puell et al., 2004; Ivers et al., 2000). Necessarily, therefore, the discussion about vision and driving focuses mainly on older drivers. This issue will gain increasing importance in future decades because of the increasing number of elderly in the population and because of increasing mobility at higher ages. Some ocular issues are however of particular importance for younger drivers. These are mainly amblyopia (reduced vision in one eye often as a result of squint) and developmental or degenerative eye disorders such as albinism or retinitis pigmentosa.

Towards a rational approach of the relation between visual functions and driving safety

We can distinguish several visual functions including visual acuity, visual field and contrast sensitivity. These functions are basically independent of each other although many disorders and diseases of the eye cause impairments in more than one function. For example: cataract leads to decreased visual acuity but also to decreased contrast sensitivity. Decreased visual acuity is usually but not always associated with decreased contrast sensitivity. For a complete assessment of vision obviously all visual functions should be considered. The current guidelines (Council Directive 91/439/EEC (1991), focus exclusively on visual acuity and visual field. Other functions, such as contrast sensitivity, glare sensitivity and Useful Field of View are not, currently, formal constituents of the standards although “twilight vision” is briefly mentioned: “when there is reason to doubt, (…) attention shall be paid to (…) twilight vision.”

Alternatively, we may distinguish functional vision (Colenbrander, 2003). This includes performance of daily life skills, including driving ability. Loss of visual function is related to the presence of eye disorders and can be described by impairment categories (e.g. visual acuity below 0.5). Loss of functional vision, e.g. loss of driving ability or performance can be described in terms of disability (e.g. loss of night driving ability). Functional vision, such as driving ability, is related to visual functions but only indirectly so (see Colenbrander, 2003). This will be further discussed in the paragraphs on restricted licences.

The aim of new standards for visual functions of drivers is to increase traffic safety by denying or restricting the driving licence of those drivers with visual impairments. Before this can be achieved, several questions should be answered.

1) Can we identify the various visual functions that play a role in driving safety?
2) Can we establish a cut-off value for each of these visual functions, below which driving is unsafe and above which driving can be allowed?
3) Do we have measurement instruments to identify those visual functions in a valid and reliable manner?

These are the questions that deal strictly with the implementation of new standards. Additional questions concern the enforcement of the standards. For example, will drivers undergo regular testing (screening) of visual function and, if so, from what age and at what intervals? This requires insight into the prevalence of impairments, the costs involved in screening and the sensitivity and specificity of tests.

Visual functions

Visual acuity.

This is the capacity to perceive small details. It is generally considered the most important modality of visual function and is tested using a character set, usually a letter chart, with characters of decreasing size, at a distance of 3 to 6 meters. Characters have high contrast (black letters on a white background) and the chart illumination is optimal. In studies on accident statistics, visual acuity was only weakly, though significantly correlated with traffic accidents and violations. The increased accident risk can be expressed as Relative Risk (or, in case of control studies, as Odds Ratio). This is the ratio between the accident risk in the impaired group and the accident risk in the control group. Van Rijn and Völker-Dieben (1999) reviewed the studies on the relation between impaired visual acuity and increased accident risk. The results are summarized in Table 1, which is copied from that review. Relative Risk values are typically below 2, with some exceptions. The most cited study is the one of Burg (1971). The data were re-analysed by Hills and Burg (1977). They found no relationship between visual acuity and accidents in young and middle aged drivers. In elderly drivers they reported a weak relationship between acuity and traffic accidents. Other studies have been published about the relationship between visual acuity and traffic safety. Hofstetter (1976) investigated 13,786 drivers and compared accidents for drivers in the lower quartile with those above the mean. In this study, a poor visual acuity led to being twice as likely to be involved in 3 accidents in the previous 12 months and 50% more likely to be involved in 2 accidents. For one accident there was no difference. Keefe et al. (2002) investigated 2594 subjects. They measured visual function and questioned people about their driving behaviour. They found that subjects with a visual acuity below 6/12 were no more likely to have a (self-reported) accident than those with a better acuity. Foley et al. (1995) found no relation between visual acuity and self-reported accidents in 1791 drivers of 68 years and older in a rural Iowa setting. Decina and Staplin (1993) correlated the visual acuity to accidents, taking self-reported mileage into account, and found no relation between isolated visual acuity and accident incidence (see also at contrast sensitivity). A small study (Lamble et al., 2002), involving driving assessment of subjects with X-linked retinoschizis (an hereditary disease in which visual acuity but not contrast sensitivity is reduced) failed to demonstrate an association between visual acuity and impaired driving performance.

From the studies, cited above, it emerges that the relation between visual acuity and traffic accidents is rather weak. Because of the importance of visual acuity in daily life (see e.g. van Rijn et al., 2002), one would assume that the relation between visual acuity and traffic accidents is strong, then why can this not be demonstrated in scientific studies? Several factors may play a role. Firstly, in these studies, the extreme values on the spectrum of visual acuities are rare: elderly subjects with very good visual acuities are rare, just as are elderly drivers with very low acuities. Therefore, in most studies, moderate acuities are compared to mildly impaired acuities, leading to only weak relations between impaired acuities and traffic accidents. Notably, the absence of low acuities in the population may (at least partly) be the result of existing regulations. Secondly, especially for visual acuity, the relation may be weakened by adaptive behaviour of the drivers. Of the elderly who have stopped driving or adjusted their driving behaviour, many did so because of visual problems (Keefe et al., 2002; Gilhotra et al., 2001; West et al., 2003) although this has been disputed by others (Holland and Rabbitt, 1992). Thirdly, the relation may be blurred by confounding variables. For example, early cataract leads to only moderate decrease of visual acuity, but also to decreased contrast sensitivity and increased glare sensitivity. Thus, the effects of cataract on contrast sensitivity and glare sensitivity may mask the relation between visual acuity and driving safety. Higgins et al. (1998) found a linear relation between visual acuity decrease (produced by optical blur) and driving performance. However, when cataract was simulated by special filters (leading to only to a mild decrease of visual acuity, but affecting glare sensitivity much more), then the effects on driving performance were much more pronounced (Wood and Higgins, 1999), suggesting that glare sensitivity is more important for driving performance than visual acuity.

Visual acuity can be measured in a valid and reliable manner. The measurements are robust (revealing identical results in various measurement circumstances) and reproducible (Hawkins, 1995; Elliott and Sheridan, 1988) and they have good face validity. This means that for most people the assessment of visual acuity for driving is considered appropriate and acceptable.

From the studies discussed in this paragraph, it appears that visual acuity is the most important measure of visual function in general and that it can be measured very well. The relation of its outcome to traffic safety is, however, rather weak. Several causes for this have been discussed above. It seems advisable in the standards to increase the role of other parameters of visual function at the cost of visual acuity. One could consider contrast sensitivity and glare sensitivity. However, as will be discussed below, measurement of these parameters is less straightforward. Until more insight has been gained into the applicability of these other parameters of visual function, the importance of visual acuity measurements for traffic safety should not be underestimated.

Table 1. *Criterion validity of Snellen acuity measurements (table from van Rijn and Völker-Dieben, 1999).*

Authors	Type	subjects	relative risk Or odds ratio	95% conf Interval	P	type
Burg,1971 (Hills&Burg,1977)	Cohort	14283	NR			
Von Hebenstreit, 1984	Cohort	663	1.17	1.06 to 1.29	0.03	RR
Davison, 1985	Cohort	1000	7.68	2.47 to 23.89	0.02	RR
Marottoli et al., 1998	Cohort	125	1.31	0.83 to 2.09	0.32	RR
Owsley et al., 1998a	Cohort	294	1.45	0.58 to 3.64	0.43	RR
Szlyk et al., 1995a	case-control	107	NR			
Rogers, 1987	case-control	?	1.37	?		RR
Von Hebenstreit, 1993	case-control	1200	1.24	0.66 to 2.32	0.62	RR
Liesmaa, 1973	case-control	1021	3	?		RR
Alsbirk, 1992	case-control	700	5.06	1.29 to 23.11	0.014	OR
McCloskey et al., 1994	case-control	683	0.78	0.39 to 1.60	0.64	OR
Szlyk et al., 1995b	case-control	20	0.12	00 to 1.72	0.16	OR
Lachenmayr et al., 1998	case-control	1004	NR			
Owsley et al., 1998b *inj*	case-control	303	1.6	0.6 to 3.8		OR
Owsley et al., 1998b *non-inj*	case-control	303	1.6	0.7 to 3.6		OR
Sims et al., 1998	case-control	174	NR			

95% conf int = 95% confidence interval; P = P value; OR = odds ratio; RR = relative risk; NR = not reported

Visual field.

The visual field is the perceptual space available to the fixating eye. The binocular visual field is the sum of the perceptual spaces available to both fixating eyes. An intact visual field provides the capacity to detect objects (or lights or movements) away from the fixation point. Impairments of visual field increase with age. The leading cause of visual field impairments in the elderly is glaucoma (e.g. Ramrattan, 2001). Visual field defects have been associated with a mild increase in accident risks. The typical relative risk values that were reported in the studies were about 2 (see van Rijn and Völker-Dieben, 1999 for an overview). A major problem in interpreting these studies is that there is no consensus regarding the definition of impairment. For example, in the classical and often cited study of Johnson and Keltner (1983), an impairment of visual field was defined as two or more adjacent targets that were missed. This may be a significant defect in clinical terms (pointing at disease) but, depending on the location of the defects, may have only a mild impact on driving performance. It has been shown that visual field sensitivities decrease with age (Haas et al., 1986; Jaffe et al., 1986) and as a result, Johnson and Keltner may have compared physiologically decreased normal visual fields with mildly impaired ones. Driving simulator studies and studies involving on-road testing of subjects with impaired visual fields, have found a strong relation between the extent of the visual field defect and driving performance: Coeckelbergh et al. (2002) demonstrated that subjects with central and mid-peripheral visual field defects drove slower and needed a longer time to react. Subjects with peripheral visual field defects had increased swaying. Tant et al. (2002), in a study with hemianopic subjects, found that generally the driving

performance of these subjects was low, although it was argued that a specific negative selection bias was present in the study. Only some subjects were found fit to drive after a specific training programme (Tant et al., 2001). Szlyk et al. (1992) found more crashes both in driving simulator tasks and state records during the preceding 5 years in 21 drivers with retinitis pigmentosa than in 31 healthy control subjects. Visual field size was the best predictor of real-world and simulator crashes. The same holds true for studies into the walking (or wheelchair) mobility of subjects with impaired visual fields (e.g. Kuyk et al., 1998; Lovie-Kitchin et al., 1990). Lövsund, Hedin and Törnros (1991) reported that individual variation in the group with visual field impairments was very large, making the group as a whole unsuitable for driving. Szlyk et al. (2002) studied driving behaviour in a driving simulator in subjects with mild to moderate glaucomatous damage. They found that driving performance was indeed related to the presence of glaucoma but interestingly in these subjects, contrast sensitivity rather than visual field defect was the relevant visual function. In a recent report, Szlyk found that visual field defects within 100 degrees correlated with driving performance and with accidents (Szlyk et al., 2005a). Hedin and Lövsund (1986) reported that in a group of 27 subjects with impaired visual fields (mostly homonymous defects) only 4 were capable of compensating for their defects. Homonymous hemianopia is a condition in which, due to a neurological cause (mostly stroke, traumatic brain injury or tumour) the visual field on one side in both eyes is blind. The consensus is that generally this condition is incompatible with fitness to drive although occasionally, subjects with hemianopia may drive safely (Tant, 2002; Tant et al., 2001; 2002). A major factor may be that visual field defects may be accompanied by other neurological and neuropsychological (e.g. attentional) deficits which can also strongly affect driving performance (Tant, 2002; Tant et al., 2001; 2002). It should be noted that probably many subjects with hemianopic visual field defects continue to drive, most often because their stroke has remained unnoticed to them (Gilhotra et al., 2002) but only few of the homonymous defects in this study were complete hemianopias.
Based on the literature cited above, it is evident that an adequate visual field is of utmost importance for the ability to drive safely. However, the actual cut-off value that should be set in the standards is as yet unclear. Further research is needed.

Experiments have been performed in which the visual field is expanded on the hemianopic side, using different kinds of prismatic devices. The success of these experiments is limited (see, e.g. Slzyk et al., 2005b) although currently other evaluation studies are being performed using alternative prismatic devices. The Eyesight Working Group does not favour the use of such devices in order to meet the visual field standards (see discussion on Bioptic devices).

Measurement of visual field with known or suspected abnormalities
For subjects with known or suspected abnormalities, visual fields are generally measured using a perimeter. This is a device that can present light stimuli at various locations in the visual field. The subject being tested is requested to indicate whether the stimulus has been seen. Most perimeters are rather costly but for this purpose, there is no alternative. In selected subjects, practice and education are needed before adequate and reproducible visual field results are obtained (e.g. Parrish, Schiffmann and Anderson, 1984; Lewis et

al., 1986; Katz and Sommer, 1990). In addition, care should be taken that any refractive error is adequately corrected prior to testing. Failure to correct the refractive error can lead to a large number of false positive measurement results (subjects with impaired results whereas they are, in reality, not impaired). (Weinreb et al., 1986; Rabineau et al., 1989; Anderson et al., 2001; van Rijn et al., 2005). Generally, visual fields are tested monocularly; binocular fields may be extrapolated from the monocular results (e.g. Crabb et al., 1998; Nelson-Quigg et al., 2000). However, for task-oriented measurement of the visual field, it would be sufficient to measure binocular fields only. Perimetry techniques can be divided into static techniques and kinetic techniques (e.g. Goldmann perimetry). Static techniques are mostly automated. In these techniques, light stimuli are presented in pre-set areas of the visual field. In Goldmann kinetic perimetry, a light stimulus is moved (manually by an examiner) usually from the periphery towards the centre of the visual field. Kinetic perimetry does not always disclose defects of significance (e.g. in retinitis pigmentosa) and at times suffers from examiner bias. Depending on the experience of examiner, central and paracentral defects may be missed. Therefore, in general, static perimetry is strongly recommended. However, in selected subjects, kinetic perimetry may still be necessary. In particular, some subjects with neurologic visual field impairment suffer from stato-kinetic dissociation (Riddoch phenomenon). This implies that moving objects (such as in traffic situations) are perceived better than static ones. Compared to age-related testing, suprathreshold screening programmes are less sensitive and may overlook, for example, the moth-eaten fields after heavy photocoagulation (as best evident with high pass resolution perimetry - ring perimetry).

Current perimetry techniques are directed at the evaluation of disease. This shows itself in the areas and size of the visual field that is being tested, the distribution of points and the evaluation of the results (comparison with age-matched controls). This makes these techniques less suitable for the evaluation of task-oriented function as is important for driving. The Esterman technique is an exception: this is a task-oriented algorithm, implemented on a static automated perimeter. This technique has not been specifically developed for the evaluation of drivers but for visual function in general. It is unsuited for driving not only because of the position of the test points but also because of its use of a fairly intense and large stimulus (III/4e). Hence, although automated perimetry using the Esterman protocol is easier to perform than standard perimetry, it is more lenient (Crabb et al., 2004; van Rijn, 2003) and we advise against it.

For this reason it is recommended to develop a ‘traffic perimetry algorithm’, analogous to the recommendations of the German Ophthalmological Society (1999). This should preferably comprise a sufficient number of test points within the area of interest. A sufficient number of those (e.g. 25) should be located in the central area of the visual field since this area is of particular importance for perception during driving and perception in general. The luminance of test points should be related to that of the hill of vision, i.e. with increasing intensity towards the periphery. With such a test at hand, it would be possible to lay down the number of missed test points, centrally as well as in the periphery, acceptable for a driving licence. Rough guidelines about the number of points that may be missed could help for a first assessment of visual fields. However, we note that expert judgement of visual fields remains very important since, expectedly, good judgement of visual field cannot be completely performed by an automated routine. Any specification which is too detailed brings with it ambiguities, especially since the characteristics of the scotomas depend on the method used to define them. We therefore suggest that, in cases of doubt, visual fields will be judged on an individual basis by a panel of specialists (possibly in a national expert centre, see section on restricted licences) although we realise that, from a practical point of view, it may be impossible that all isolated defects will be judged on an individual basis. We therefore suggest that some rough guidelines should be developed to discriminate between those defects that are allowed, those defects that are not allowed and those that should be referred to a specialist centre for further judgement.

Measurement of visual field for screening purposes
For screening subjects with a low likelihood of visual field defects, perimetry may be less efficient since it requires rather costly equipment. There are simple devices that test the ability to detect LEDs along the horizontal meridian but their capacity to detect field defects is not known. Often, the Donders confrontation method is advocated for screening purposes. In this confrontation method, the visual field is tested by an examiner using hand movements. The sensitivity and specificity of this method are very low (e.g. Johnson and Baloh, 1991; Shahinfar et al., 1995) except perhaps for hemianopic visual field defects (Shahinfar et al., 1995). For the purpose of screening the visual fields of healthy licence candidates, there is a need for a simple, reliable and quick test that could be administered by any person.

Contrast sensitivity.

This is the ability to distinguish grey letters on a white background. This simulates the conditions during driving at night when objects to be detected are more similar in contrast to their surroundings than during daylight conditions. A subject with impaired contrast sensitivity may, for example, have difficulty in detecting a dark-coated pedestrian at night (e.g. Wood et al., 2002). In the absence of ocular disease, contrast sensitivity is related to visual acuity (Brown and Lovie-Kitchin, 1989), but in specific ocular diseases, such as cataract (Anderson and Holliday, 1995) and age-related macular degeneration (Kleiner et al., 1988), contrast sensitivity may be more affected than visual acuity.

Contrast sensitivity has been found to have a stronger relation with traffic accidents and violations than visual acuity, although the number of available studies is low. Marottoli et al. (1998) found a Relative Risk of 2 for accident involvement for Pelli-Robson contrast sensitivity values below 1.35. Owsley et al. (2001) found that drivers with a crash history were 8 times more likely to have a Pelli-Robson contrast sensitivity of below 1.25 than drivers who were crash free. Dunne et al. (1998) found that drivers with impaired low contrast acuity had twice as many crashes as those without. Pfoff and Werner (1994) found that cataract surgery leads to increased contrast sensitivity and decreased glare sensitivity and that subjects increased their night-time driving frequency after cataract surgery, even though visual acuity was above 0.5 before (and after) surgery. Wood and Troutbeck (1995) found that simulated cataract in normal subjects leads to impaired driving performance. This simulated cataract was associated with decreased UFOV (see later) and contrast sensitivity scores. Anderson and Holliday (1995) found a strong correlation between simulated cataract and decreased contrast sensitivity for moving targets during night-time, even though visual acuity was unimpaired. Szlyk et al. (1995) found that macular degeneration was associated with decreased driving performance in a simulator, but not to increased risk in real world due to adaptive behaviour. Notably, in the macular degeneration group, both visual acuity and contrast sensitivity were reduced. Mäntyjärvi and Tuppurainen (1999) investigated drivers with early cataract and found that, even when visual acuity is still 0.5, contrast sensitivity, glare and photostress may be severely disturbed. Szlyk et al. (2002) found that decreased driving performance in a driving simulator of subjects with mild to moderate glaucomatous defects was associated with their decreased contrast sensitivity (and not with their visual field defects). Even so, contrast sensitivity was only mildly decreased in these subjects. Wood (2002) found that decreased vision caused by simulated cataract by filters was better associated with contrast sensitivity than with visual acuity. Decina and Staplin (1993) correlated the visual acuity to accidents taking self-reported mileage into account and found no relation between isolated visual acuity and accident incidence but did find a relation between accidents and a combination of visual acuity, visual field and contrast sensitivity in drivers aged 66 and over.

From the studies cited above, it appears that contrast sensitivity may provide important information about the visual capacity of drivers in addition to the measurement of visual acuity alone (Brown and Lovie-Kitchin, 1989). The problem is that we do not know yet what cut-off value should be imposed upon contrast sensitivity measurements. We do know that impaired contrast sensitivity affects driving performance but we do not know what level of contrast sensitivity is acceptable and what level is not acceptable. Further study is needed. When considering implementation of contrast sensitivity standards, the prevalence of impairments should be considered carefully. In a recent study into the prevalence of vision impairments in European drivers (van Rijn et al., 2005), it was found that contrast sensitivity values (Pelli-Robson below 1.25) are very rare in young drivers, but are present in 1.7% of drivers between 65 and 74 years of age and in 6.3% of drivers of 75 year and older. Values between 1.25 and 1.5 are present in an additional 19.1% of drivers of 75 years and older. Thus, although the actual definition of impaired contrast sensitivity for drivers still needs to be established, it seems that the prevalence of impairments is much higher than the prevalence of impairments of visual acuity and visual field.

There are several methods for measuring contrast sensitivity. In the literature, the best method for testing contrast sensitivity is considered to be the Pelli-Robson chart (Pelli, Robson and Wilkins, 1988; Elliott, Sanderson and Conkey, 1990; Rubin, 1988), but there are several other generally accepted methods. The problem with these methods is that there are no normative data available across these test methods and across measurement centres. This implies that the outcome of one particular test cannot be related to the outcome of other tests and that each measurement centre should develop its own normative database for the results (D.B. Elliott, personal communication). Furthermore, there is no clear cut-off value established for (one of) these tests. Notably, in the European prevalence study (van Rijn et al., 2005) there were marked differences in the prevalence of contrast sensitivity impairments, which should probably be attributed to differences in measurement conditions. This was despite the fact that particular attention was paid to harmonise the experimental setup across participating clinics. Finally, these tests have been developed for the evaluation of disease in a clinical setting. In such a setting, there is no vested interest for the applicant in having a good test outcome. Therefore, little attention has been paid to the "cheat resistance" of the test methods. For example, the Pelli-Robson chart has only three alternatives for each level of testing. This could easily be memorised.

In summary, contrast sensitivity can provide valuable information about the visual capacity of drivers. Before proceeding to implementation, measurement methods and cut-off values should be further developed.

Glare sensitivity.

This is the sensitivity to glaring light sources such as a setting sun or the headlights of approaching cars. Subjects with increased glare sensitivity may be more easily blinded in such conditions. Studies on accident statistics of subjects with increased glare sensitivity revealed high relative risk values (von Hebenstreit, 1995; 1984; Lachenmayr et al., 1998 reported relative risk values of, respectively 11.04, 1.59 and 2.42). A major problem is that the number of studies is only small and that the technique for measuring glare sensitivity in those studies is not well developed (van Rijn et al., 2005). Moreover, in those studies, the number of impaired subjects was up to 45% (von Hebenstreit, 1995), disqualifying this technique as a tool for discriminating between impaired and non-impaired drivers. Another study (Owsley et al., 2001) failed to demonstrate a role for glare sensitivity. In an on-road simulation study, Theeuwes et al. (2002) found that headlight glare (mounted on a car) caused decreased recognition of objects along the roads, especially by elderly drivers. Skaar et al. (2003) found that increased glare sensitivity correlated with decreased visual attention in elderly drivers. Simulated cataract, produced by filters (leading only to a mild decrease in visual acuity and selectively affecting glare) appears much more detrimental for driving performance than decreased visual acuity produced by optical blur (Higgins, Wood and Tait, 1998; Wood and Higgins, 1999).

A major problem is that a suitable measurement technique has been lacking, due to the fact that glare sensitivity is largely condition-dependent (Elliott and Bullimore, 1993; van Rijn et al., 2005). Recently, the gold standard for measuring glare sensitivity (straylight measurement) was converted into an instrument that is suitable for use outside research laboratories (Franssen et al., 2005). It is likely that in the near future field experience with this technique will be available so that its applicability for assessing drivers can be more readily judged. This technique has been used in a study into the prevalence of visual impairments among European drivers (van Rijn et al., 2005). It was found that the prevalence of impairments (defined as straylight values above 1.4) is very low at young ages and rises to almost 30% above 75 years of age. However, the adequate cut-off value for this measurement technique still has to be established.

From the studies, cited above, it emerges that glare and straylight may be important parameters of visual function for driving safety. However, before implementation of glare measurements could be considered, the measurement technique should be more thoroughly evaluated and adequate cut-off values should be established.

Useful field of view (UFOV).

This parameter may seem somewhat misplaced in this report since it is not a test of 'traditional' visual function. However, UFOV has been shown to be relevant for predicting fitness to drive and because of its relation to visual functions it will be discussed. The UFOV tests the ability to perform simultaneous detection tasks (divided attention) in a visual surrounding crowded with visual distractors. By doing so, it combines a purely visual task with a neuropsychological task of attention. It is tested by a custom-made programme on a personal computer, or by a custom-made test device. In studies on accident statistics, high relative risk values have been reported (Owsley et al., 1998a; 1998b and Sims et al., 1998 reported values of 2.8; 4.2-17.2 and 6.1, respectively). Several studies (e.g. Owsley, et al., 1991; Ball et al., 1993) demonstrated that early dementia and attentional factors in general are very important factors contributing to the unfitness to drive of elderly subjects . The visual attentional component is probably the basis for the observed relation between UFOV tests and driving performance. However, simulated cataract has also been associated with decreased UFOV scores (Wood and Troutbeck, 1995), although the stimulus was such that it should have been seen with low visual acuities. However, since UFOV is not a test of basic visual (ocular) function, the interpretation of the test results is not always straightforward. As Withaar (2000, cited in Tant, 2002) reports, the importance of task-specific experience may blur the direct relation between neuropsychological function (as tested in UFOV) and driving. The authors, promoting the UFOV, have reported that practice enhances UFOV performance but it is unclear whether this has an effect on driving performance and whether the effect is sustained. Roenker et al. (2003) reported that training the speed of processing improved both driving performance (in a simulator) and UFOV score. On the basis of these data, we conclude that the UFOV may be useful as an additional (vision related) test to assess individual drivers. However, due to the difficulty in interpreting the results, it seems at present unsuited to include the test in the European vision Directive.

Diplopia

Currently, diplopia is only mentioned in the paragraph for Group 2 drivers. It should be noted that diplopia can be severely disabling and can severely affect driving performance. Long-standing diplopia, especially when present before the age of 10, is influenced by higher cortical function and many people with strabismus report having diplopia , when asked specifically. However, they are able to ignore the second image, in most cases to the extent that they hardly perceive this second image anymore. In contrast, newly developed diplopia in an adult may be incapacitating because these people cannot suppress one image and may not be able to distinguish between the two images. When the diplopia persists for months, in many cases, but not always, some kind of adaptation and suppression of one image occurs so that driving, at least for Group 1 drivers, could be allowed. It is therefore important for newly developed diplopia, to request an adaptation period as well as a complete ophthalmological examination. For Group 2 drivers, driving with diplopia should probably never be allowed. Intermittent patching of one eye during driving (in order to avoid diplopia) is not recommended because it hinders adaptation. Patching of one eye is, however, a useful option when the patch is worn continuously (ie not only during driving). In this case, rules for monocular drivers apply. We note that there is very little literature about diplopia and driving. We know of only one paper that describes a limited number of subjects with acquired diplopia (White et al., 2001). In this small study, there was no difference in driving behaviour (driving simulator) between subjects with long standing acquired diplopia (longer than 6 months) and normal controls.

Bioptic devices and other visual enhancement devices

Visual aids may be divided into devices for correcting refractive errors (to focus the image onto the retina) and devices that modify the image in other ways. These latter devices may enlarge the image, to enhance resolution, or they may shrink the image, in order to expand the visual field (e.g. Szlyk et al., 1998). Alternatively, they may change the location of the image (prismatic devices) in order to prevent diplopia or expand the functional visual field (e.g. Szlyk et al., 2005b). Bioptic devices are spectacle-mounted telescopic devices that provide a solution for low visual acuities. Their use for drivers has been advocated by a number of researchers (e.g. Katz, 1991; Politzer, 1995), but fundamental research into their benefits and disadvantages has been scarce (see, e.g. Szlyk et al., 2000). Although bioptics are allowed in many states of the USA, their application remains controversial (e.g. Barron, 1991). The central field of view is enlarged by a telescope in order to enhance resolution. As a result, the user may be able to identify characters that belong to a visual acuity 0.5 standard whereas the acuity, when measured conventionally, is lower. This enlargement of the telescopic image area is at the cost of the introduction of a large ring scotoma when looking through the telescope. The ring scotoma blocks an area 'Magnification x the field of the telescope'. For a common '3 x 12 telescope, this results in a 36 degrees diameter scotoma. Anything outside this area (hence from 36 degrees to the actual peripheral limits of the visual field) remains visible. Therefore, the driver is instructed to look through the telescope selectively only when he/she "needs" a better acuity, particularly for reading road signs. From research into the use of bioptic devices, it appears that there is a large variation in the estimate of the percentage of time that people use them, although the tasks were very similar (Bowers et al., 2005). Some people estimate that they spent a large amount of driving time looking through the telescope but most people hardly used the telescope. According to the instructions, people should look through the telescope no more than 5 to 10% of driving time. However, after passing the driving test wearing the device, most people subsequently rarely look through the telescope at all.

The Eyesight Working Group acknowledges that bioptic devices may be helpful to the individual driver (e.g. Szlyk et al., 2000). However, by allowing bioptics under all conditions, it is felt that visual acuity standards would be significantly lowered at the cost of a severe reduction in visual field. The effect on traffic safety of this reduction may be marked. Notably, depending on the magnification factor of the device, the 0.5 visual acuity standard could be effectively reached even with very low visual acuities but at the cost of the ring scotoma, as mentioned before. In many states in the United States, reasonable limits are placed on visual acuity *without* bioptics in order to avoid this issue. Analogous to this, we recommend that bioptic devices may be considered only when: 1. the driver demonstrates safe and adequate driving behaviour *without* the use of bioptics **and** 2. it is demonstrated (preferably by a practical driving test) in this individual driver that the use of the bioptic does not interfere with traffic safety. Hence, the bioptic device should not be used to meet the standard, but may be used during driving provided that the subject is well adapted to using the device. Notably, in the United States, a large variation in rules apply in the various states (see, e.g. at www.lowvision.org for a comprehensive overview. Most states allow bioptics for driving but only 23 states also allow use of the device to meet the visual acuity standard. Fourteen states explicitly forbid this and another 14 states do not mention bioptics. In many states, visual acuity standards are lower than in European countries although, it must be realised, traffic conditions are markedly different). The Eyesight Working Group realizes that, without lowering the current acuity standard, the usefulness of bioptic devices is limited. Bioptic devices may be especially useful with low visual acuities, possibly as low as 0.16. However, the general opinion across the Working Group members is that in the European traffic setting, it is not desirable to lower the acuity standard to such a level.

Periodic screening of drivers

Having discussed the relationship between driving performance and the various visual functions, and having discussed the problems of the cut-off values, the next question is whether drivers should be periodically screened for impairments of vision and, if so, from what age and at what intervals. In the European Council Directive 91/439/EEC, there are no guidelines regarding periodic testing of drivers. In most member states, however, some form of medical evaluation takes place upon driving-licence renewal either by self-declaration by the driver or by a physician, who can be a general physician or a designated specialist. (see White and O'Neal, 2000 for an overview).

The advantage of screening is obviously the promotion of driving safety by a reduction of the number of fatalities and injuries attributable to functional impairment of the driver. The disadvantage of screening lies in the costs that are involved and the effort that is required of the driver. In the literature, the effectiveness of periodic screening has been doubted. Most knowledge originates from studies comparing traffic safety in drivers with and without in-person renewal of driving licences (Kelsey and Janke, 1983; Zaidel and Hocherman, 1986; Janke, 1990; Grabowski et al., 2004). None of these studies reported any beneficial effect of screening of visual functions. Zaidel and Hocherman (1986) demonstrated that, although 30% of drivers were instructed to start wearing spectacles for driving, only 7% did so as a result of the screening procedure. Janke (1990) reported that driving licence renewal by mail (as opposed to in-person renewal) did not affect traffic safety in subjects with clean driving records (although there was a difference in subjects with previous driving accidents and convictions). Grabowski et al. (2004) reported that in-person driving licence renewal was associated with lower fatality rates in elderly drivers, although vision tests were not beneficial. In a recent study into the prevalence of impairments of visual function in European drivers (van Rijn et al., 2005), the highest prevalence of impairments was found in sub-populations in which screening was mandatory (Spain at any age and The Netherlands beyond the age of 70). Although one could argue that *without* screening, the prevalence would have been still higher, these results cast doubt on the effectiveness of screening of visual functions. Only Shipp and Penchansky (1995) extrapolate to a possible beneficial effect of screening.

Screening should only be imposed if its efficacy and efficiency are well established. The efficacy and efficiency of screening are determined by the prevalence of impairments, the sensitivity and specificity of the tests that are being used and the costs of the screening procedure in relation to its benefits (enhancement of traffic safety). This should preferably be evaluated in a prospective randomized study (see Wormald, 2003 for a comprehensive review). The prevalence of impairments was recently investigated in the European study mentioned above (van Rijn et al., 2005). It was found that the prevalence of impaired visual acuity and visual field is very low at young ages. The prevalence of impaired visual acuity rises to 5% in the highest age groups (consisting of drivers of 75 years of age and older) but the majority of these subjects meet the standards after proper adjustment of their spectacle correction. The prevalence of impairments of visual fields rises to 2.7% in the highest age groups. The prevalence of impairments of contrast sensitivity and glare sensitivity is higher but the cut-off value of those parameters is not yet clearly established. As yet, these visual functions are not included in the European Directive. Screening may be particularly useful to improve spectacle correction amongst drivers since it has been repeatedly found that up to 10% of drivers may have a considerable improvement of visual acuity when their spectacle correction is adjusted. However, it is as yet unknown whether screening of drivers will indeed promote wearing of adequate spectacles, and additionally, if wearing those spectacles will positively influence traffic safety.

In conclusion, screening may be most beneficial for the detection of impaired contrast sensitivity, increased glare sensitivity and possibly reduced Useful Field of View. For these parameters of visual function, no standards are as yet defined. Further research is recommended. Screening for detection of impaired visual acuity and visual field is of limited value since the prevalence of impairments amongst drivers (at least at young ages) is limited. If, due to a desire to harmonise European standards, screening of drivers is to be introduced then we recommend it should only commence at older ages and preferably not before the age of 60.

Exceptional cases: restricted licences

Under the current Directive, it is possible to offer a restricted licence to drivers. Codes 05.01 to 05.04 restrict driving respectively to day-time, a certain radius, without passengers or with a speed limit. Additionally, the validity of the licence may be time - limited. There is no guidance as to how these codes or limitations should be applied. We note that the relationship between vision impairments and driving performance is rather weak. The weakness of this relationship is caused by the fact that driving performance is determined multifactorially. Apart from vision, many factors play a role. Vision impairments may sometimes, but not always, be compensated for by (strategic or tactical) behaviour of the driver (Keall and Frith, 2004). Hence, the relation between impairments and activities (e.g. driving) is indirect. (ICF terminology, see e.g. Tant, 2002 for a discussion of these terms, see also Colenbrander, 2003). That is, the same impairment (e.g. low visual acuity) does not always lead to the same limitation (e.g. practical unfitness to drive) because a (mild) impairment can sometimes be compensated for.

A lowered visual acuity is often accompanied by an impaired contrast sensitivity and/or glare sensitivity. This is particularly true for elderly subjects with cataract, glaucoma or macular degeneration. As has been pointed out above, measurement procedures for contrast sensitivity and glare are not well developed. Therefore, we do not advocate a lowering of the visual acuity standard since this may have the unwanted side effect that subjects with rather severe impairments of contrast sensitivity and/or glare sensitivity will be granted a licence. The consequence of this strategy is that there is a limited number of subjects (e.g. with stable congenital / hereditary disease such as x linked retinoschizis) with suboptimal acuity, but normal contrast sensitivity and glare sensitivity, who are denied a licence, although they could be safe drivers because their 'isolated' mild impairment and preservation of other visual functions facilitates effective compensation. A similar reasoning holds for visual field defects caused by (posterior) brain damage. In many cases, only the visual field is impaired without other visual functions being affected.

For this group, where a mild impairment does not lead to a substantial limitation, we advocate formalising the procedures for restricted licences. Driving performance should be investigated by a practical driving test. Once the subject has demonstrated adequate compensation, a restricted licence may be offered. We note that limitations of vision, such as decreased visual acuity and contrast sensitivity, may particularly affect driving performance during twilight hours. Therefore, restricted licences in subjects with these sight limitations could be issued for day-time hours only. In addition, the driving radius could be limited to limit exposure and to facilitate driving in a familiar setting where unanticipated traffic situations are minimized. The validity in time of the driving licence could be limited in cases of possible progressive impairments. A system like this would, to a large extent, enhance the mobility and social independence of the mildly visually impaired population. Moreover, by requesting a practical driving test and by imposing restrictions and limitations, traffic safety may be optimally safeguarded. However, we emphasise that a restricted licence should be issued in exceptional cases only and following positive expert advice. Moreover, the applicant has to demonstrate adequate driving ability. Notably, the applicant should be tested under the conditions for which a licence is applied. The driving test should be passed in the area of intended driving. This will avoid passing the test in a rural area whereas driving occurs in an urban setting and vice versa. If twilight driving is applied for, this should also be tested. Hence, only in exceptional cases and following positive expert advice and evaluation, can restricted licences be issued to candidate drivers not attaining the visual standard (to be discussed further). Advice and evaluation should be undertaken only by vision and driving experts, preferably in specialised multidisciplinary centres.

As suggested, a restricted licence should be possible only when the visual impairment is moderate and hence if the visual function is just a little below the standard and other visual functions are nearly unimpaired. The consensus amongst the Working Group members is that, when a driver applies for a restricted licence based on suboptimal visual acuity, the actual visual acuity should not be below 0.3 whereas other visual functions, such as contrast sensitivity and glare sensitivity, should be unimpaired (values to be defined). Moreover, the visual field standard must be met in full. Alternatively, when the application is based on a limited visual field, then the actual visual field defect should be outside the central 20 degree area and the standard regarding visual acuity must be met. This field value of 20 degrees is based on the observation that this area is of particular importance for visual perception during driving (Schiefer et al., 2000). Hence, a restricted licence should not be possible when both visual acuity and visual field are below the standard. (Some Working Group members also support the possibility of a restricted licence for those with homonymous visual field defects, caused by brain damage.)

The vision and driving experts decide upon the validity of the driving licence and the potential restrictions. It should be emphasised that, if the applicant challenges the decision, the burden of proof should rest with the applicant. The applicant for a restricted licence should prove that he/she is capable of driving under the conditions for which a licence application is made. We recommend that national specialist centres (or at least a limited number of specialist centres in each country) be responsible for the issuing of restricted licences. These ‘fitness to drive centres’ should house, amongst others, vision and driving experts. This would facilitate procedures and would generate a large pool of experience in this field. Furthermore, this would allow for future comparison of data for research purposes.

Conclusions

From the studies cited above, it appears that a variety of parameters of visual function is important for safe driving. This holds true particularly for visual field. Contrast sensitivity and, perhaps, glare sensitivity are also very important. Visual acuity, especially if only mildly impaired, seems less important, but we note the majority of conditions that lead to decreased visual acuity also lead to decreased contrast sensitivity and increased glare sensitivity. As we noted, measurement of contrast sensitivity and, particularly glare sensitivity is less straightforward than measurement of visual acuity, since we lack knowledge about adequate cut-off values and about the prevalence of impairments in the driving population. As long as adequate testing for contrast sensitivity and/or glare sensitivity is not included in the standards then it is advisable not to underestimate the role of visual acuity measurements.
Regarding the actual cut-off values, we have remarked that research data are lacking for various reasons. The recommendations that follow in the next paragraph are therefore based on reasoning, common sense and practical experience. It is advisable that research is performed specifically into the issue of cut-off values. Awaiting the results of such investigations, we feel that some recommendations can however be made.

Principles of testing

1) Parameters should be defined in terms of visual function, not in terms of test outcomes.

2) Parameters should be defined in terms of visual function, not in terms of ocular disease.
3) The term “normal” should not be used.
4) Parameters should be defined binocularly. When defined monocularly, this should be justified.
5) Test parameters should be clearly defined in order to avoid ambiguity.
6) The majority of the tests should be laboratory tests, in order to avoid frequent on-road testing procedures.

Current guidelines and proposed changes

In the paragraphs below, the headings represent the current European Directive. Each heading is followed by a discussion of problems and recommendations

Group 1

1) **The binocular visual acuity should be 0.5 or better.**
   a) Problem
      i) The rationale for this cut-off value has not been properly justified.
   b) Recommendation
      i) Depending on the contrast sensitivity and glare sensitivity of the driver and on the road and traffic conditions, the standard of 0.5 for visual acuity may be too strict (daytime driving in a subject with non-impaired contrast and glare sensitivity) or too lenient (night-time driving in a subject with early cataract) (Elliott et al., 1996) We emphasise that the effects of lowered contrast sensitivity and increased glare sensitivity can be such that visual performance may be drastically reduced, depending on sight conditions. Therefore, even whilst 0.5 is probably a rather high standard, it should not be lowered until adequate testing procedures for contrast sensitivity and, possibly, glare sensitivity, are available.
2) **The horizontal visual field should be at least 120 degrees**
   a) Problems
      i) This cut-off value has not been properly justified
      ii) There are no requirements for the left/right/up/down extension of the visual field
      iii) There are no guidelines for the testing method
      iv) There are no requirements regarding the absence of/allowance of sporadic defects
      v) There are no rules regarding the number of attempts a candidate is allowed to make.
   b) Recommendations
      i) Many studies demonstrate the importance of an adequate visual field for driving, however, adequate cut-off values have not been published. Awaiting studies in this field, there is no current basis for change of this standard. Additional research is recommended.
      ii) The solitary requirement for the horizontal extension of the visual field does not exclude the possibility of important extensive visual field defects above

and below this meridian, defects of significant importance in traffic. Although, as pointed out, scientific data to support figures concerning the recommended extension are lacking, it is reasonable to propose that the visual field should extend to 20 degrees above and below the horizontal meridian. Likewise, the field must not be too limited on either side of the fixation point. We therefore suggest a minimum of 50 degrees to the right and to the left.

iii) For an adequate examination of a candidate's visual field, it is necessary to perform perimetry. This test is costly, since it requires rather expensive equipment. It is also time consuming. Since the prevalence of visual field defects in the driving population is rather low, it may not be necessary to test all driving licence applicants by perimetry. It could be sufficient to test only those individuals in whom defects could be anticipated. Those individuals, should preferably be tested by a 'traffic perimetry algorithm'. This should comprise a sufficient number of test points (e.g. 100) within the area of interest (i.e., 120 x 40^o), from which a sufficient number of points (e.g. 25) is located within the central 20 degrees (radius). Their luminance should be related to that of the hill of vision, i.e., with increasing intensity towards the periphery. The luminance should be at a certain supra-threshold level; we suggest 8 dB above the threshold for older people (e.g. 80-years old). Visual fields could be measured binocularly (ie with both eyes together). When visual fields are measured monocularly, only defects that are overlapping, i.e. at the identical location in both eyes, should be considered .Visual field defects that are not overlapping (a visual field defect in one eye with no defect at the identical location in the fellow eye) are less relevant for driving. With such a test available, it would be possible to lay down the number of missed test points, centrally as well as peripherally, acceptable for a licence (see at iv)).

iv) Within the suggested 120 x 40^o area, isolated field defects (depressions, scotomas) may appear, e.g. due to glaucoma or chorioretinitis. If of a certain depth and size, they might be of significance in traffic. There are no data suggesting the maximum number, size and depth of such defects. Monocular drivers are (as far as we know) not hampered by the Physiological Blind Spot. Therefore a comparable scotoma in the binocular visual field could be allowed. It is reasonable that scotomas within the central 20^o (an area with a diameter of 40^o with the fixation point in the centre) are of greater importance than scotomas outside this area (Schiefer et al., 2000). Any more detailed specification brings with it ambiguities, especially since the characteristics of the scotomas depend on the method used to define them. We therefore suggest that isolated defects be judged on an individual basis by a panel of specialists (possibly in a national expert centre, see section on restricted licences). We realise that, from a practical point of view, it may be impossible for all isolated defects to be judged on an individual basis. We therefore suggest that some rough guidelines should be developed to discriminate between those defects that are allowed and those that should be referred to a specialist centre for further judgement. These guidelines could, for example, be as follows: *with the method of testing, suggested at iii), within the central 20 degrees of* *visual field (radius) no more than 2 relative defects should be present. When these defects are related to the Physiologic Blind Spot, these defects may be absolute. Within the 120 (horizontal) x 40 (vertical) degrees visual field area, no more than 7 relative visual field defects should be present.* It should be noted that these criteria could only provide a rough guide to the judgement of visual modalities. We strongly advocate further research in this field to further justify these criteria. It should be realised that relative defects are sensitive to refractive errors. Therefore, prior to testing, refractive errors should be adequately corrected. Moreover, relative defects in peripheral visual field areas may be generated by spectacles and spectacle frames. It is common practice for diagnostic tests to test peripheral visual field areas without spectacle correction, in order to avoid inadvertent measurement of visual field defects, but this does not reflect the actual situation during driving.

v) We know that visual field testing results may be variable; first time testing often has worse results than repeated tests (e.g. Parrish, Schiffmann and Anderson, 1984; Lewis et al., 1986). Therefore, one has to allow for repeated testing in case of doubt. The adequacy of the test results may be judged by an expert.

3) **No progressive eye disease should be present, when a progressive eye disease is present, regular check-ups are requested.**
   a) Problem
      i) None, this is an adequate standard
   b) Recommendation
      i) None

4) **In case of total functional loss of vision in one eye, the visual acuity must be at least 0.6.**
   a) Problem
      i) This is an ambiguous standard since, for example, mere light perception in the fellow eye is not useful for driving, but is not absolute blindness.
      ii) No functional difference is anticipated between monocular and binocular drivers, other than in functions that are not tested for, such as stereo-acuity.
   b) Recommendation
      i) No special requirements for the monocular driver: this paragraph could be omitted.

5) **There are no requirements for twilight vision, other than in cases of doubt.**
   a) Problem
      i) Tests for twilight vision may supply useful information about driving capacity.
   b) Recommendation
      i) There is no clarity regarding the cut-off value and methodology of measurement for contrast sensitivity and the cut-off values for glare sensitivity. However, it is likely that impairments of twilight vision are an important factor in road safety. Therefore, future introduction of requirements regarding twilight vision should be made possible and anticipated, after proper research has been performed.

6) **There are no requirements for the absence of diplopia**
   a) Problem
      i) Diplopia may lead to severe confusion of images during driving. Note that adaptation is possible in many cases and that severely disabling persisting diplopia is rare.
   b) Recommendation
      i) Formulate a requirement regarding diplopia e.g. no severely disabling diplopia should be present. Any recently developed diplopia should lead to an adaptation period of at least 6 months, during which driving is not allowed. After this period, driving is only allowed after favourable support of vision and driving experts, suggesting that the diplopia is not disabling. Intermittent patching of one eye during driving (in order to avoid diplopia) is not recommended as it limits adaptive processes. Patching of one eye is an acceptable option when the patch is being worn continuously (hence not only during driving). In this case, rules for monocular drivers apply.

Group 2

1) **The visual acuity should be at least 0.8 in the best eye, 0.5 in the fellow eye.**
   a) Problem
      i) The visual acuity requirement for the fellow eye is insufficiently justified. One may argue that driving is a binocular activity and therefore no requirements for monocular visual acuity should be formulated. However, one may also argue that, in view of the greater responsibility of Group 2 drivers, a spare eye should be present. Even if one should require a spare eye, it is safe to assume that with a visual acuity of 0.1 in this spare eye, a driver should be able to stop the truck or bus at the side of the road.
      ii) The cut-off value of 0.8 in the better eye is arbitrary, although we consider it reasonable in Group 2 drivers to expect that the visual acuity is normal or near normal.
   b) Recommendation
      i) We recommend changing the visual acuity requirement in the fellow eye from 0.5 to 0.1.
      ii) We recommend no change to the standard of 0.8 in the better eye.
2) **Glasses should be +- 8 dioptres or less**
   a) Problem
      i) This requirement is not formulated in terms of visual function and therefore it may lead to ambiguities. The ring scotoma that results from +8 Dioptre glasses depends on the shape of the glasses, the distance of the glass to the eye and on the shape and thickness of the spectacle frame. Therefore, the visual field restrictions that result from these glasses largely vary between subjects. Notably, most +8 Dioptre spectacles will result in visual field defects well within the 120 degree area. However, at present insufficient knowledge is available to formulate a justifiable change of this requirement. In contrast, -8 Dioptre glasses will not result in a ring scotoma.
   b) Recommendation

   i) The –8 requirement could be abolished. No requirements for the strength of minus lenses need to be formulated. We note that severe myopia leads to decreased visual acuity and contrast sensitivity (Risse et al., 1996), but these visual functions could be tested separately.
   ii) The +8 requirement requires further research. Possibly, in the future, this requirement may be formulated more precisely (e.g. +8 dioptre glasses are only allowed if, with the glasses, adequate visual fields can be demonstrated).

3) **Normal visual fields should be present in both eyes.**
   a) Problems
      i) The term "normal" is ambiguous since the extent of the visual field depends on the shape of the face. Hence a "normal" visual field in one subject may in fact be smaller than an "impaired" visual field in another subject.
      ii) One may argue that driving is a binocular activity, therefore no monocular visual field requirements should be formulated. Even in terms of a spare eye (potentially necessary for stopping the car in case of emergency) no monocular visual field requirements are necessary.
      iii) The cut-off value is arbitrary, although it is reasonable to expect from a truck or bus driver that the visual field is unimpaired.
      iv) There are no guidelines for the testing method.
      v) There are no rules for the number of attempts a subject is allowed to make.
   b) Recommendations
      i) Formulate the visual field requirements in terms of numbers, e.g. horizontal visual field should be 160 degrees, the extension should be at least 70 degrees left and right and 30 degrees up and down. No defects should be present within central 30 degrees (not even the Physiologic Blind Spot). The exact numbers should follow from future research.
      ii) The requirements are for binocular visual fields, see section on Group 1 drivers.
      iii) See at i)
      iv) See at section on Group 1 drivers. The method for Group 2 drivers may be similar, though the reference age may be different, e.g. 70 years of age. This would effectively request that a Group 2 driver has a sensitivity throughout the visual field that is not more than 8 dB worse than the normal sensitivity of a 70 year old subject. The actual requirements require further research.
      v) See section on Group 1 drivers.

4) **No requirements for twilight vision (contrast sensitivity and/or glare sensitivity) are included.**
   a) Problem
      i) Twilight vision may provide useful information about driving capacity
   b) Recommendation
      i) There is no clarity regarding the cut-off value and methodology of measurement for contrast sensitivity and the cut-off values for glare sensitivity. However, it is likely that impairments of twilight vision are an important factor for adequate driving performance. Therefore, future introduction of requirements for twilight vision should be made possible and anticipated, after proper research has been performed. In the opinion of the

Working Group, it is reasonable to expect unimpaired contrast sensitivity in a Group 2 driver. Future research should reveal how this will translate into the outcome measures of visual function tests.

5) **Requirements for the absence of diplopia are scarcely formulated.**
   a) Problem
      i) Diplopia may lead to severe confusion of images during driving. Note that adaptation is possible in many cases and that severe, disabling persisting diplopia is rare.
   b) Recommendation
      i) Although driving could probably be allowed for drivers with long-standing, non-disabling diplopia, research on this issue is scarce. We recommend not changing the current standard. (i.e. we recommend that Group 2 drivers should not have diplopia).

General

1) **There are no requirements for periodic testing nor on procedures in case of the development of eye disease between testing periods.**
   a) Problem:
      i) Eye disease that occurs after the licence has been granted will not be detected and any gradual decrease in visual functions will remain unnoticed.
      ii) Even if a person knows that she/he has developed an eye disease, there is currently no obligation to inform the authorities and be tested.
   b) Recommendation
      i) Research is advised into the efficacy and efficiency of periodic screening. The questions to be answered concern the prevalence of impairments (currently being studied), the specificity of testing and cost of screening procedures in relation to the costs of accidents. This should preferably be evaluated in a prospective randomised study. If screening is implemented, based on current knowledge, then we recommend starting at a rather late age for Group 1 drivers and not before the age of 60. For Group 2 drivers, testing at a younger ages may be considered, as well as a test at the first application for the driving licence.
      ii) In cases of newly developed ocular disease or decrease in vision, drivers should be examined or re-examined. It should be the responsibility of drivers to make sure that the visual function requirements are met (e.g. by checking with their ophthalmologist). In cases of doubt, a full ophthalmological assessment should be performed.
2) **There is a difference between screening (aimed at detection of disease) and testing (aiming at measuring known abnormalities)**
   a) Problems
      i) Applying testing programmes to a normal population may be costly and lead to a large number of false positives
      ii) Applying screening programmes to subjects with known abnormalities may lead to false negatives
   b) Recommendation.

i) The requirements that are formulated above are applicable for testing subjects with known abnormalities. The conditions for screening need to be formulated. For example:
(1) Measure visual acuity of both eyes with habitual spectacles
(2) Measure visual field with a suprathreshold screening programme.
(3) If any abnormalities are found, refer for a testing programme.

3) There is no adaptation period following newly developed eye disorders.

a) Problem.

i) For example: after trauma in which a subject loses one eye, the requirements regarding Group I licences are still met. However, in the immediate aftermath of the trauma, the subject may not be capable of driving safely due to adaptation problems, but driving capacity may be regained (Edwards and Schachat, 1991). The same applies to the occurrence of diplopia after brain disease.

b) Recommendation

i) Formulate a standard as follows: (Group I) after the loss of vision in one eye or after newly developed diplopia, there should be an adaptation period of at least 6 months during which the subject is not allowed to drive. (Group II) after substantial loss of vision in one eye (and the driver still meeting the requirements) there should be an adaptation period of at least 6 months during which the subject is not allowed to drive. In both cases, the driver is obliged to check with their ophthalmologist whether the requirements are still met. In case of doubt, a full ophthalmological assessment should be performed.

4) There is only a limited opportunity for a restricted licence (exceptional cases).

a) Problem

i) In some drivers, mild perceptual defects may be compensated for by adaptive driving behaviour. These drivers may not adversely affect traffic safety, whereas stopping them from driving would introduce a large social handicap. Such compensation may occur both for visual acuity and visual field defects.

ii) In some subjects with stable sub-optimal visual acuity and normal contrast sensitivity and glare sensitivity, this standard of 0.5 may be too strict.

iii) The experience with restricted licences in member states is limited and decentralized.

b) Recommendation

i) and ii) Allow the possibility of issuing a restricted licence for Group I drivers when visual acuity is between 0.5 and 0.3 or, alternatively, when visual field defects are present outside the central 20 degrees area, in both cases subject also to favourable support from vision and driving experts. The applicant should demonstrate adequate driving performance in the conditions for which the licence application is made. This implies that also a practical driving test should be performed. In practce, this could imply that an elderly subject with impaired visual acuity (and no significant impairments of contrast sensitivity and glare) is granted a licence with restrictions to day-time hours and to a certain radius. A young subject with a stable congenital disease may be, for example, granted a licence with day time restrictions, but without any limits to exposure, depending on expert advice. A restricted licence should not be issued when the visual acuity is below 0.3 or when visual field defects are present within the central 20 degrees of visual field (radius). (As has been mentioned above, some members of the Working Group support the possibility of a restricted licence for subjects with homonymous hemianopia due to brain damage). A restricted licence should not be possible when both visual acuity and visual field are below the standard.

ii) See at i).

iii) The Working Group advocate the establishment of national specialist centres to deal with the issuing of restricted licences. These 'fitness to drive centres' should house, amongst others, vision and driving experts.

5) There is a pressure from interest groups to allow driving with Bioptic devices.

a) Problem

i) Driving with bioptics allows the driver to meet the standard of visual acuity (when looking through the telescope device) òr meet the standard of visual field (when looking past the telescope device). Hence, they do not meet both standards at all times. Apart from this, it is likely that in selected subjects, a bioptic device may be a useful tool to enhance visual performance during driving.

b) Recommendation

i) A bioptic device may be a useful tool during driving. Its application should only be considered when the driver has demonstrated that its use does not interfere with driving performance (i.e. that the driver is well adapted to using the device) e.g. by a practical driving test. Bioptic devices should not be used for the purpose of meeting the standards on vision. Hence the standards should be met without the bioptic device.

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